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A FLASH FLOOD IN WESTERN DERBYSHIRE

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Flash floods are destructive, short-lived torrents in the headstream valleys of drainage basins, and are caused by very rapid run-off during intense downpours of rain. In Britain they only occur when prolonged and abnormally heavy thundery rains affect restricted areas, but their importance is disproportionate to their infrequency because they accomplish much geomorphological work in very short periods of time. The development of stream valleys in youthful and sub-mature landscapes cannot well be understood without an appreciation of the fact that a flash flood may accomplish as much erosion and deposition in half an hour as the stream in its normal condition will effect in decades or centuries. It is of interest to geographers to examine how far these phenomena depend upon particular meteorological, geological, morphological and land-use factors, and how they influence such features of the cultural landscape as the siting of settlements, and optimum land use. This paper is concerned with a flash flood which affected several left-bank tributaries of the River Dove on 6 August 1957.

The proximate cause of the flood was thunderstorm rain of exceptional weight and high intensity, in synoptic circumstances which are coming to be recognised as responsible for many, if not most, of the more exceptional falls of rain in the north Midlands (1). The severe thunderstorms of 5-6 August 1957 were associated with the interaction between an upper cold pool and a small surface low pressure system which approached each other over west central Britain, and passed together across the region.

At midday 4 August a cold upper trough lay well to the south-west of the British Isles and was moving slowly eastwards, while a small surface low was travelling slowly northwards across northern Biscay. By midday 5 August the upper trough covered the western British Isles, and an upper cold pool, a separate cut-off circulation within the upper trough, had appeared and was centred over western Ireland, while the Biscay low had moved north into the west-central English Channel area and adjacent southern England. By midnight 5-6 August the cold pool was over the central Irish Sea, and the centre of the surface low south of the Bristol Channel. Severe thunderstorms were already affecting the Shrewsbury and Birmingham areas, especially between 10 p.m. and midnight, when over 1.3 inches of rain flooded the World Scout Jamboree Camp in Sutton Coldfield Park, Elmdon airport recorded 1.185 inches and Edgbaston observatory considerably more, probably over 1½ inches. This group of storms affected the upper Tame basin, but the rainfall was insufficient to cause river flooding. During 6 August the upper cold pool crossed from North Wales and the north Irish Sea to the central North Sea. The Biscay low turned eastwards and moving slowly at first, but accelerating towards evening, it followed a track parallel to that of the cold pool into the southern North Sea. As the two systems moved into parallel tracks the heaviest rains were transferred across the north Midlands and southern Pennines into the East Riding before

(1) The synoptic conditions resembled in some important respects those of 1 July 1952, when rainfalls of intensities classified as "rare" affected parts of Derbyshire and Nottinghamshire, and many stations had "noteworthy" falls.

midnight 6-7 August. Although scattered thunderstorms broke out widely under the influence of the cold pool, the most severe storms occurred in a relatively narrow zone from south-west to north-east where air, warmed on a land track in the circulation of the surface low, was flowing north-westwards beneath cold air moving east and north-east aloft in the south-east sector of the cold pool.

South-west Derbyshire and adjacent Staffordshire received their heaviest rainfalls in the early morning of 6 August, some hours after the main Birmingham storms. The distribution of rain was typically irregular. Uttoxeter received a total fall of 2.16 inches on 5-6 August. A gauge near Hatton recorded 2.14 inches. Further north 2.84 inches were registered at Shirley in the 24 hours to 9 a.m. 6 August, 2.70 inches having fallen by 8.30 a.m. At Brailsford, only about 2½ miles south-east of Shirley, only 0.5 inches were measured, but little more than one mile west of Shirley the gauge at Rodsley pumping station collected 5.97 inches in the 24 hours to 10 a.m. 6 August. A proportion of this rain fell on 5th, and before 3 a.m. on 6th, but the great bulk fell between 5 and 10 a.m. 6th, when Rodsley must have been affected by a succession of mature thunderstorm cells. A mean intensity of at least 1 inch an hour for this period of 5 hours is a fair estimate for Rodsley, but must obscure periods of greater intensity, and notably one around 8 a.m. on the evidence of eye observations in the district.

Local observers agree that the "centre of the storm" was over Darley Moor. Taking account of the upper wind, the probable size of the thunderstorm cells and the relative positions of Shirley, Rodsley and Darley Moor, it is not unreasonable to suppose that Darley Moor received a fall at least as heavy as Rodsley's. Some very tentative estimates of run-off rates for the Foston and Snelston Brook basins, based on later surveys of cross-valley profiles and estimated flood discharges derived from these, suggest rainfalls of the order of 5 to 8 inches (if sustained for 5 hours) in Darley Moor, and a fall for the day of 5 inches appears to be a conservative estimate. All accounts agree that heavy rains affected this area from 5 a.m. onwards, and these would have the effect of filling drainage channels and saturating the ground in comparatively level or gently sloping areas, so that a final intense downpour following immediately at about 8 a.m. would run off almost at once.

The streams most seriously affected, the Clifton, Snelston, Foston and Hilton Brooks, are shown with their headwaters and tributaries and the boundaries of their drainage basins in Figure 1. The physical character of the country through which these streams flow is important in an interpretation of the consequences of the intense rainfall. Apart from the Brailsford Brook, a tributary of the Hilton Brook, the streams flow entirely over Triassic rocks. Apart from local cappings of glacial drift most of the area is Keuper Marl, but there is some variety in the watershed area, where Keuper Waterstones and Bunter Pebble Beds are also represented.

Keuper Marl is comparatively impervious, and surface drainage is intricately developed upon it. The profuse tributary pattern produces a landscape that is closely dissected by numerous minor stream valleys. However, this part of the Dove-Derwent interfluve preserves portions of several well-marked erosion surfaces. In particular there are two considerable fragments south of Ashbourne of a level surface cut at about 580 feet O.D., the Darley Moor surface described by K. M. Clayton (1953),

with a subsidiary level about 30 feet lower. The Yeaveley surface at 470-495 feet, with a subsidiary Bentley Hall stage at about 460 feet also occur in the area which received the heaviest rainfall. The more southerly fragment of the Darley Moor surface is cut in Keuper Marl or marly Waterstones beds, and in its natural state its drainage is sluggish. It will be noted that the headwater streams which radiate from it generally rise near its present boundary, related to contours rather than geological outcrops. The surface may be regarded as a collecting area which in its natural wooded state drained slowly enough to its peripheral valleys to have some effect in regulating the flow of the streams.

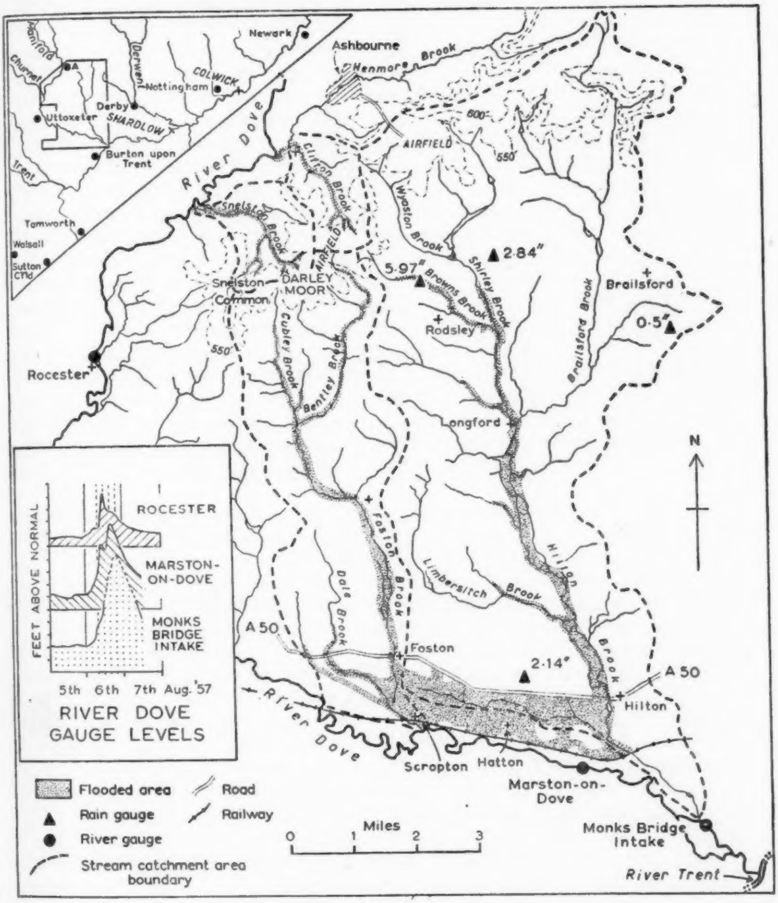

Fig. 1
The flooded brooks and river gauge levels on the Dove.

The valleys grade steeply down from the Darley Moor surface before flattening, but are in the broadest terms fairly smoothly graded, as would be expected of valleys cut in material as weakly resistant as

the Keuper Marl. In detail, however, this is not the case. Many of the streams now flow in their upper parts in narrow, often wooded gorges known as dumbles, sometimes containing small waterfalls over skerry outcrops, which are common in these lower Keuper Marl and Waterstone beds. For example, the main headstream of Snelston Brook flows in a dumble up to 20 feet below field level for the first mile of its course down to Brook Farm, where it is joined by the Alley Brook flowing in a similar gorge. The combined stream, now flowing over Waterstones, soon enters another dumble section on its way down to the Dove. These dumbles, incised within the headstream valleys, are evidence of rejuvenation at a comparatively recent date, and the waterfalls indicate their still imperfect grading. Since they occur in the uppermost sections of the stream valleys the rejuvenation apparently is not a consequence of a fall in base level working back upstream. The increased erosive power to which the dumbles testify points to an increased discharge, reflecting an increased rate of run-off, and not a steepened gradient and consequently increased speed of flow below a migrating knick point. The dominant discharge which controls valley (as distinct from channel) development acts only intermittently, in times of exceptionally rapid run-off, and its value and frequency must surely have been increased by the clearance of natural woodland for cultivation from pre-historic times onwards, and especially in the early medieval period from which most of the settlements in this area date. Incision has been rapid compared with the rate of valley widening by the processes of mass movement under gravity. Dumbles are well-known in the Keuper Marl area of Nottinghamshire, and are there attributed by Professor Swinnerton to a similar cause. Their development is sometimes associated with a headward extension of the incised stream at a measurable rate after woodland has been cleared or drainage improved around the stream source. The Cocker Beck, north-east of Nottingham, provides a good example of the process.

This discussion is relevant because land-use changes on Darley Moor during the 1939-45 war have set the scene for further geomorphological development of the kind described in that area. Before 1939 the poorly-drained area of Darley Moor was well wooded. Advantage was taken of the level but elevated character of the Darley Moor surface by building airfields during the war both on Darley Moor itself and on the more northerly fragment of the surface near Spitalhill. In this latter area the surface is cut mainly in Bunter Sandstone, which is much more freely-draining than the Keuper Marl of Darley Moor ; it carried little or no woodland in 1939. Thus no very great change in drainage conditions was brought about. But on Darley Moor much woodland was necessarily cleared and there was a rigorous improvement of the naturally sluggish drainage, which was directed into the headwaters of some of the streams which rise nearby. The construction of the Darley Moor airfield must have lowered the critical weight and intensity of rainfall required to cause flash floods in the valleys draining from it, and increased the severity of such floods as would have occurred had Darley Moor remained undisturbed. The factors responsible for dumble development have been reinforced, and the stream valleys radiating from Darley Moor have become subject to further adjustment. It is in this context that the effects of the abnormally heavy and intense rainfall of 6 August 1957 should be examined. The considerable damage sustained by old-established settlements, roads and bridges, which is

next briefly reviewed stream by stream, suggests that before this new stage of development was initiated conditions had for long been comparatively stable.

Clifton Brook

With a total drainage area of only 1.78 sq. miles the Clifton Brook system heads in three small streams rising on or near the north-east side of Darley Moor. The thalweg is steep as far as Clifton, the only valley village. The most westerly, and main headstream, rising in an area from which woodland has been cleared (Holly Wood) and receiving the drainage of the northern sector of the airfield, spread far beyond its usual confines in its uppermost course, and damaged the Edlaston-Clifton Road and the culvert which normally carries the brook beneath it. In the steep meadow below severe biting and slipping of the banks effected a very substantial enlargement of the slightly incised stream trench, and by its severity emphasises the significance of the recent changes in land use. The smaller, middle headstream rising near Edlaston Hall also damaged its culvert and destroyed the retaining wall at the same road, no more than 200 yards below its source. At Dobbinhorse Lane the combined stream flowed across the road 100 feet wide, leaving a deposit of sand and mud, and a few hundred yards below it wrecked a stone access bridge to Hollies Farm. From this point nearly to Clifton the A515 road parallel to the brook was flooded up to 2 feet deep, and below this the flood torrent severely damaged the gardens of the Hall and vicarage, flooded the vicarage, and, surging across the A515 road on a wide front at the lower end of the village destroyed a concrete footbridge and deposited a mass of sand, mud and debris. At Clifton the rain was most intense between 8 and 8.45 a.m., and the flood reached the village about 7.45, was highest at 8.45, receding by 9.45, and by noon the brook was only bank-full.

Snelston Brook (Fig. 2)

The flash flood on this brook was more damaging than that on the Clifton Brook, which may be related to the fact that the course of the latter crosses Bunter country in its upper part, and consequently dumbles are not well developed and run-off would be less severe. Snelston Brook, draining 2.24 sq. miles, has two chief upper systems, the Snelston Brook proper and the Alley Brook. The Snelston Brook heads in three small streams rising on Darley Moor, and airfield drainage is led into the middle of the three. The main, most easterly headstream, first seen at the A515 road, flows for its first 750 yards in an overgrown dumble up to 18 feet below field level, incised in a shallower valley, and is then joined by a similar but smaller stream. Two hundred yards below another stream from Cinderhills Wood joins it. The combined stream, flowing over Keuper Marl, demolished the downstream face of a bridge carrying an access road and blocked its culvert with stones and gravel up to 10 feet deep, stretching back 30 yards—a measure of the erosion along the courses of these normally tiny brooks. Several trees were washed out and caused obstruction in the heavily wooded dumble below. Two small waterfalls over bands of skerry sandstone were cut back at the lips, and 10-feet deep holes scoured below them, at the exits from which the gorge was left choked with timber and pieces of rock from the fall lips.

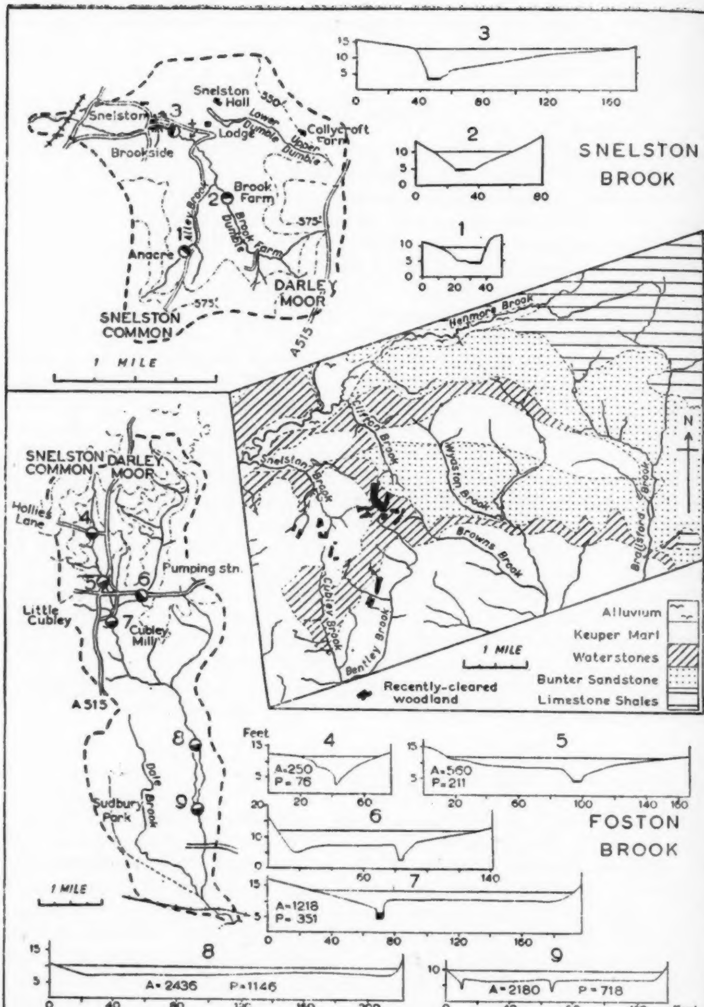

Fig. 2

Flood sections across the Snelston and Foston Brooks, and geological outcrops of the watershed area.

At Brook Farm, about a mile below its source, the stream emerges from Lower Brook Farm Dumble and passes through a culvert beneath a farmyard, and along the farm road in an extended ford to the fields below. Normally only an inch or two deep, the brook rose 8 feet above normal, covered the farmyard to a depth of 4 feet and flooded outbuildings 3 feet deep; rose to the bellies of cows which had been tethered for milking; swept away milking equipment and churns, one

of which was recovered at Rocester ; spread the debris from a wall 50 yards downstream ; overturned a 5-ton cattle transporter and deposited it 50 yards downstream ; carried a tractor shed and two 1½-ton tractors, all overturned, about 10 yards. The flood was at its peak at Brook Farm at about 8.30 a.m.

Alley Brook, rising a mile away on Snelston Common, a westward continuation of Darley Moor, joins Snelston Brook near Brook Farm. It too flows in a dumble in its upper course, and where it emerges to join a second small stream on the Waterstones it normally flows round cottage gardens, two inches deep in a ditch 18 inches deep. Fed by broadly channelled sheet flood, from which Holywell Cottages only 400 yards from the watershed on Snelston Common were flooded to a depth of 2 feet shortly after 8 a.m., the swollen brook coursed across the gardens below the dumble, removing 2 feet of top soil and parts of the nearby road surface. Flooding began shortly before 8 a.m., reached a peak at 8.20, receded markedly between 9.0 and 10.30 and the stream was back to normal by noon. The flood was thus roughly synchronous with that on the upper Snelston Brook. Much debris, including stones up to 2 feet in diameter, was deposited at the exit from the dumble.

Below Brook Farm the flooded stream stripped crop and top soil from part of a cabbage field before entering a further section of winding dumble. The Snelston-Anacre road crossing it was flooded to a depth of 6 feet. A right-bank tributary flowing through a dumble into Snelston Park added its quota. The yard of Collycroft Farm was flooded to a depth of over one foot by surface water coursing down to this brook from a portion of Darley Moor surface cut in Keuper Marl and Waterstones to the north of it. The lake in Snelston Park filled and overflowed shortly after 8.15, and the Hall and Lodge were both flooded.

Part of Snelston village alongside Snelston Brook suffered damage. Along "Brookside" one house was flooded over 6 feet deep, and its garden shrubs and hedges were flattened and 75 hens lost; at Keeper's Cottage opposite water reached half-way up the windows ; below this three adjacent cottages were flooded above the door lintels ; and where the brook leaves the village at Three Horse Shoes cottages the ground floor rooms were flooded to within 9 inches of the ceilings. Here the brook was 10 feet above its normal level. It swept over the road, submerging the bridge under 3 feet of water, and was powerful enough to snap a 7-foot gritstone gate post and carry the three-quarter ton fragment 78 feet across a field. From the road to the Ashbourne-Uttoxeter railway line, hedges and crops were flattened in a strip now 300 yards wide, and banks of gravel and stones up to one foot diameter were left. The next road was crossed 4 feet deep, and the flood met the railway on a 500 yard front, washing away at least 400 tons of ballast as it swept into the Dove.

The heaviest rainfall in and around Snelston occurred between 7.0 and 8.0 a.m., and it was most intense from about 7.40 until 8.0. Flood damage in the village occurred between 8.15 and 9.15, the flood being at road level along Brookside by 8.45, and clear of the houses there by 10 a.m.

Foston Brook (Fig. 2)

The Foston Brook system drains about 12.5 sq. miles in a north-south strip of country some 1½ to 2 miles wide. About 1,500 acres were

flooded, mainly in the lower part of the basin, but the behaviour of the two main headwaters, the Cubley and Bentley Brooks was very similar to that of the Snelston Brook.

Cubley Brook rises between Darley Moor and Snelston Common on Keuper Marl, very near the source of the Snelston Brook, and it was therefore affected by the same storms. Moor House, only a little below the Cubley-Bentley Brook watershed, was flooded one foot deep by sheet flood about 8 a.m., testifying to the intensity of the rain over another part of its catchment area. Cubley Brook rose between 6 and 9 feet above normal, flooded roads crossing it and destroyed culvert facings, flattened hedges and flooded houses south of Cubley Post Office.

Bentley Brook, rising on the disused airfield on Darley Moor, wrecked the bridge carrying the Cubley-Alkmonton road. A tiny tributary entering it there, only 300 yards long, but entrenched 8 to 10 feet into the Keuper Marl, was filled with gravel and boulders for the last 70 feet of its course, and some 200 tons of debris were deposited where it enters Bentley Brook.

Near Cubley Mill a road embankment crosses the wider course of the combined Foston Brook, which normally flows in one culvert through the embankment, two other culverts being used also by normal floods. A large hay stack was carried bodily from a field above Cubley Pumping Station, across two roads, and piling against an alder grove helped to block the culvert near Cubley Mill. The two other culverts proved inadequate, flood water built up behind the embankment, and overflowing produced a spectacular waterfall 140 yards wide before the embankment was breached. Downstream, with the flood front steepened by this check, similar damage was suffered by roads, bridges and culverts and almost all hedges and fences were swept flat in a track about 300 yards wide. Mill Farm, Cubley, and Rectory Farm, Boyleston, were flooded, buildings demolished, and vehicles carried away, including a 17 cwt. car at Rectory Farm, which was carried, overturned, 200 yards downstream.

At Foston, where the brook cutting through the Hilton Terrace before gaining the Dove flood plain passed normally beneath one arch of a three-arched stone bridge carrying the main Derby-Stoke road (A50), the flood approached as a wave six feet high, and the first destructive impact, followed by scouring at the piers as the bridge was submerged 2½ feet deep, caused its collapse within a few minutes. A Bailey bridge now replaces it. Cottages upstream of the bridge were flooded to a depth of 6 ft. 6 inches. A workman at the fishponds below heard the bridge collapse, saw the advancing flood, and was able to warn the inhabitants of Scropton and Hatton before the water reached them. The catchment upstream of the bridge is about 6,600 acres, and the discharge was probably at least 6,000 cusecs.

Reaching level country, but prevented from entering the Dove by the inadequacy of the culvert through the embankment of the main Derby-Uttoxeter railway line, flood water spread more widely, but more slowly towards Scropton, and eastward towards Hatton. The flood damage in this area was different in character therefore from that in the more restricted stream valleys. Twenty-five houses were flooded at Scropton and Foston, 12 of them over 2 feet deep, but at Hatton 293 houses—nearly the entire village—were flooded, 69 of them to more than one foot. A new school and an uncompleted Council housing estate

were affected, and some poultry were lost, but the damage was caused by submergence alone.

In the middle Foston Brook valley the flood was characteristically short-lived, and moved quickly. Mill Farm house was entered at 7.40, was flooded most deeply between 8.0 and 8.30, and the flood was receding by 10.30 and was within banks again about noon. At Rectory Farm the brook overflowed about 7 a.m. but the flood peak reached Boyleston between 8.50 and 9 a.m. The flood wave arrived at Foston Bridge at about 9.15. Flood water began to spread eastwards across the fields above Scropton about 8.30, but this must have been caused by local rains. The flood wave from Darley Moor thus arrived along a brook course which was already in flood, and Scropton was flooded between 10.30 and 11 a.m.

Hilton Brook

Flooding was less severe in the Hilton Brook system. The main brook is supplied by two main headwater systems. The more westerly Shirley Brook, known as Wyaston Brook above Osmaston lakes, heads on the more northerly fragment of the Darley Moor surface on Keuper Marl and Waterstones, but half its course is across Bunter Sandstone. It also receives drainage fron the western side of Darley Moor. Brown's Brook, which joins Shirley Brook below the lakes, rises on the edge of Darley Moor itself, and flows mainly across Keuper Marl and Waterstones. The Rodsley gauge, only 300 yards from Brown's Brook recorded 5.97 inches for the day, and the catalogue of flooded roads, damaged culverts, flooded houses—for example Rose Cottage and Shirley Mill—resembles that for the other flooded brooks. By contrast the Brailsford Brook, the more easterly headwater system, was never much more than bank-full, and contributed little to the flooding of the Hilton Brook below Longford, for rainfall was much less over its catchment area—only 0.5 inches at Brailsford—and the headwaters flow from the Limestone Shales north of the Triassic outcrop.

The contribution of the Shirley Brook was sufficient to cause abnormally high discharge below its junction with the Brailsford Brook. Roads were flooded at Longford, near the confluence, at Mammerton Farms and Bartonfields. At Longford and at Hilton weirs normally 7 feet high were drowned. Houses at the Bent on Limbersitch Brook were flooded. At Hilton Gravel Company's office the flood arrived suddenly, bursting through a hedge at a point where the brook normally turns near A516. The road and 8 houses were flooded. Below this the Hilton Brook flood waters merged with those of the Foston Brook spreading east from Hatton.

Down the Hilton Brook valley flooding persisted for increasing periods downstream. The road below the lakes at Shirley Mill was flooded from 7 a.m. to 11 a.m. At Longford Hall the brook was bank-full at 7.30, rose to a peak between 8.45 and 9 a.m. and was not clear of the Derby-Rocester road until 3 p.m. At Hilton the fields began to flood about 10 a.m., and the water rose until noon. After falling a few inches in the next half-hour the level rose to a new peak which was maintained for an hour, and by 5 p.m. it had only receded one foot.

Dale Brook and Sudbury Park Stream

While not comparing in weight with the total rainfall further north, the 2.14 inches measured near Hatton indicates falls heavy enough to cause flooding on two minor streams. That rising in Sudbury Park over-

flowed the A50 and A515 roads, and flowed down Leathersley Lane to Scropton. The Dale Brook, rising at Harehill, overflowed to flood cottages at Dalebrook. Below the crossing of A50 the floodwaters gradually extended to join with those of the Foston Brook below the fish ponds. This local flooding was apparent near Scropton by 8.30 a.m., about an hour before the flood wave arrived down the Foston Brook.

Henmore Brook

The heavy rains over the Darley Moor surface, running off the abandoned Spitalhill airfield and the surrounding area, flooded down the main road (A52) into Ashbourne, and caused slight wash-land flooding on the Henmore Brook just above the town. Heavy rain in Ashbourne overwhelmed the storm water drains soon after midnight, and several streets were flooded by 2 a.m., but the Henmore Brook just failed to rise enough to flood the A52 road where it crosses the stream in the town.

Travel of the Flood Peaks

The rate of travel of the flood peaks on the various streams produced by the final intense downpour in the Darley Moor area varied considerably with the form of the flood channel and the gradient. Local accounts suggest that the peak travelled the length of the Clifton Brook in a little less than one hour, to arrive at its outfall into the Henmore Brook at about 8.55 a.m. Snelston Brook flood peak reached its outfall into the Dove at about 9.25. Apart from a minor peak at 5 a.m. the Rocester river chart indicates one flood peak arriving at 10.15, suggesting that the Clifton and Snelston peaks arrived at the Snelston Brook-Dove confluence at about the same time, and the combined peak travelled downstream to Rocester at an average speed of about 4.85 m.p.h. Comparison with the record at Marston-on-Dove shows that the average speed of the flood crest between Rocester and Marston was about 3.63 m.p.h. These rates compare with estimated averages of 2.55 and 2.04 m.p.h. for the steeper Clifton and Snelston Brooks, the slower rate of the latter being related to its generally more sharply incised course. On the Foston Brook the speed reached about 4 m.p.h. between Cubley Mill and Foston Bridge, but fell to only 1 m.p.h. as the flood spread more widely between Foston bridge and Scropton. The noon peak at Hilton indicates a speed of 1.92 m.p.h. between Longford and Hilton on the Hilton Brook, while the water wave reaching Hilton an hour later had travelled from Foston at only 0.93 m.p.h.

These estimates show that the speed of the flood crest was markedly lower in the steeply graded but narrow dumbles of the Snelston Brook than in the Dove and the lower-middle Foston Brook, which are less steep, but whose channels are more nearly adjusted to the discharge. The flood crest travelled most slowly where the flood spread most widely beyond the stream channel and the gradient was low.

The water level as registered by the gauge post on the Dove near Scropton rose steadily to a maximum at 4.40 p.m. 6 August. Unfortunately the Intake recorder went out of action at 12.30 p.m. 6th, but the final peak was not observed there until after 7 p.m., and the final combined peaks probably arrived at the Dove-Trent confluence between 8 and 9 p.m. At Shardlow the Trent rose by 3½ feet, a 2-hour peak arriving at 4 a.m. 7 August. Downstream of Colwick, 15½ miles below Shardlow, the level of the Trent rose about 2 feet to a peak at 6.45 a.m.

7th, but the required speed of travel indicates that this could not represent the Shardlow peak, but should probably be identified as that recorded on the Derwent on the evening of 6 August. The level at Colwick remained within 3 inches of the peak for 9½ hours and the peak corresponding to that at Shardlow, just above the Derwent confluence, probably arrived at Colwick about 11-12 a.m. 7th. If this were so it would indicate a speed which, applied to the Trent above Shardlow, would point to a peak at about 8.30 p.m. 6th at the Dove outfall, which accords with the earlier estimation.

Some very approximate estimates given below indicate discharges in the flooded brooks of an order which could be expected to show up in the records of level of the main rivers, although they were insufficient to cause flooding. For example about as much water was passing down the tiny Snelston dumble as flows past Trent Bridge Nottingham in a normal dry period, and the discharge which wrecked the bridge at Foston was several times greater. But in a rainy period when the main streams were already above normal levels, and when convective rainfall was irregularly distributed in both space and time over the wider region of the Trent basin, the individual stream floods were so much smoothed and merged with other contributions that they became undiscernible individually in the Trent record.

Rates of Run-Off

An attempt has been made to estimate flood discharges and run-off rates on Snelston and Foston Brooks by calculation from surveyed valley sections and gradients, and the use of Manning's formula for velocity ($v = \frac{1{\cdot}486\, m^{\frac{2}{3}}\, i^{\frac{1}{2}}}{n}$ where m = area of cross section/wetted perimeter, i = inclination, and n = Kutter's coefficient indicative of the roughness of the valley course). The probable degree of error in the calculations is considerable because n was assigned the value of 0·06 for Foston Brook and 0·08 for the more restricted though steeper Snelston Brook without any experimental check. Flow calculations were made for both upstream and downstream gradients from the points of cross section, and there is a good chance that the true value lies somewhere between. However, the figures should be regarded as indicating only the order of the discharges.

TABLE I
FLOOD DISCHARGES in cusecs.

	Cross-sect. area (sq. ft.)	*Wetted perimeter*	*Discharge*		
			Upstream	*Downstr.*	*Average*
Cubley Brook					
Hollies Lane ..	250	76	1,931	1,689	1,810
A515 Bridge ..	560	211	3,274	2,286	2,780
Foston Brook					
Cubley Mill.. ..	1,218	351	—	4,867	—
Sapperton	2,436	1,146	6,823	6,243	6,533
Broomhill	2,180	718	7,076	6,140	6,608
Snelston Brook					
Brook Farm ..	162	51·1	982	457	719
Anacre Hill ..	90	31·8	749	423	586
Keeper's Cottage ..	600	137·2	2,670	1,380	2,025

(n = 0·06 Foston Brook, 0·08 Snelston Brook)

Bentley Brook, rising on Darley Moor, and another smaller stream join the Cubley Brook between A515 and Cubley Mill, so that the difference between the downstream values for these two points gives a rough estimate of discharge in the lower parts of these two tributaries. On account of their relative drainage areas most of the 2,561 cusecs should be assigned to the Bentley Brook, which probably added the order of 2,200 cusecs to the discharge of the Foston Brook.

If the flow downstream of Broomhill on the Foston Brook was not less than 7,076 cusecs, then at Foston Bridge the run-off for the Foston Brook was about 1,045 cusecs per 1,000 acres, which is equivalent to an intensity of 1.05 inches an hour over the whole area. If the flow at Snelston Brook outfall was 1,380 cusecs, this is equivalent to a run-off of 1,556 cusecs per 1,000 acres, or an intensity of 1.56 inches an hour. These figures relate to the maximum flood flows, but suggest run-offs of the order of 2 inches or more an hour in the area of maximum rainfall and at the time of maximum intensity. These figures are entirely appropriate in order of value for run-off produced by a well developed thunderstorm cell precipitating in its mature phase over an area where run-off was immediate because ground was saturated and drainage channels charged by previous prolonged heavy rainfall.

Conclusion

The previous major flood in the Foston-Scropton-Hatton-Hilton area was in February 1946, when the Dove overflowed near Sudbury. The floods under discussion were not comparable because at 10.30 to 10.45 a.m. 6 August 1957 there was a fall of water surface level of 4 feet from Scropton Ford to the nearby Dove, and the Dove can have taken no part in the flooding, which was caused essentially by the rapidity of run-off in the headwater area of the Foston and Hilton Brooks.

A report by the Engineer to the Trent River Board suggests certain remedial measures in the lower reaches of the south-flowing streams, that is, in the Dove Valley—the construction of cross flood banks to confine flooding of individual streams, the building of more effective openings through the railway embankment into the Dove, enlargement of the Foston Brook channel below Foston, and the elimination of the lake at Foston Hall(1). The report implies that no remedial measures of an engineering character are practicable in the upper catchment area where these floods mainly originated, since "Rainfall of such high intensity is a very rare occurrence, and it would be uneconomical to provide even bridge openings and road levels to cope with such excessive run-offs in the upper reaches of the various streams". While this statement as it stands is unexceptionable, and while it is true that such a weight of rain is comparatively rare, our records of rainfall, and particularly of intense convectional rainfall of irregular distribution, are so short and incomplete that they are not amenable to statistical analysis to estimate risk, and no-one knows how rare such falls are. The very rarity of such damaging floods in these valleys, as suggested by their severe effects on old-established settlements and bridges, is a reason for viewing this occurrence with concern in view of the recency of the changes on Darley Moor. It has been argued above that the risk of flash floods in the headstreams flowing off Darley Moor has been

(1) The streams were not "main river", and the River Board had no direct responsibility for, or jurisdiction over them. Repton R.D.C. has urged that the Foston and Hilton Brooks should be "mained".

appreciably increased by the destruction of woodland and the improvement of drainage in that area during the war(1), and this flood might well be interpreted as a warning of the possible consequences of deforesting and over-draining impermiable watersheds, even in England. Since the airfield is now disused it is appropriate to suggest that attention might be given to the land use in this area, and re-afforestation suggests itself as a possible measure of control which might benefit both the upper and lower stream valleys, especially since woodland planted on a sufficient scale yields financial returns which could be set against the loss of the land for other uses.

* * * * *

REFERENCE

K. M. Clayton, "The denudation chronology of part of the middle Trent basin", *Institute of British Geographers, Transactions and Papers 1953* (1954), pp. 25-36.

(1) The fact that some authorities may believe that afforestation does not retard run-off on steep slopes is not relevant here, for this is a comparatively level area in which conscious improvement of drainage has had the specific object of increasing the rate of run-off.

THE LEICESTERSHIRE AND SOUTH DERBYSHIRE COALFIELD

(1) The Coal Mining Industry

W. D. Holmes

Introduction

The Leicestershire and South Derbyshire coalfield forms a small industrial region in the midlands of England, characterised by its basic heavy industries of coal mining and clay extraction and associated manufacture, and diversified by engineering, textiles, and a small amount of other light industry. It lies astride the county boundaries of north-west Leicestershire and south Derbyshire, having a total length of 16 miles and a maximum width of 8 miles. It covers an area of approximately 78 square miles (including the newly-explored western extension) of which 53 square miles are in Leicestershire (Fig. 1).

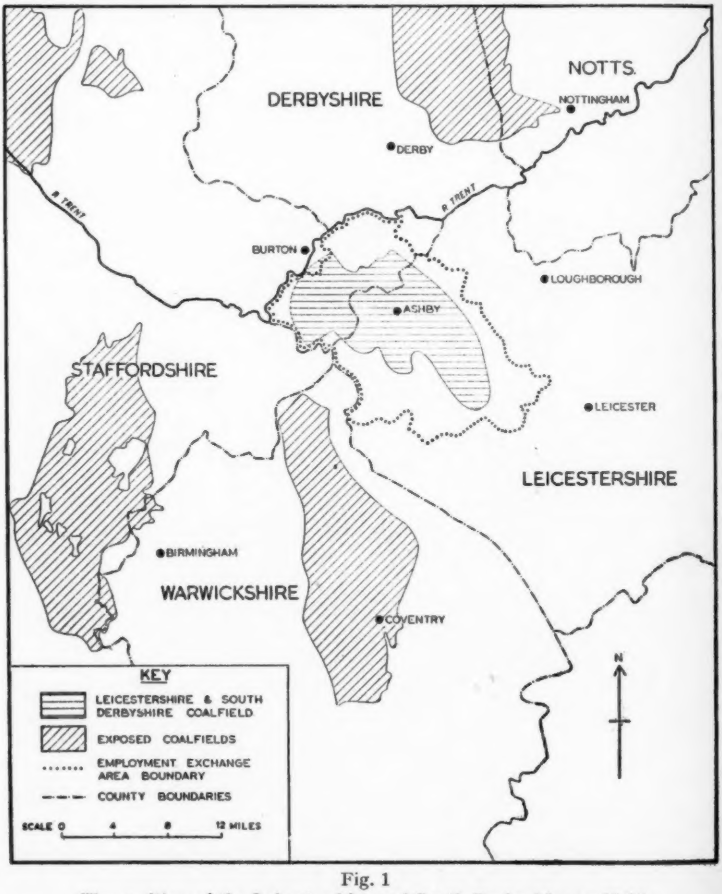

Fig. 1
The position of the Leicestershire and South Derbyshire coalfield.

Although structurally isolated from the main Derbyshire and Nottinghamshire fields, it forms No. 7 Area of the East Midlands Division of the N.C.B. The whole of the region falls within the three Employment Exchange Areas of Coalville, Ashby-de-la-Zouch and Swadlincote. These Areas form a convenient administrative unit for which relevant statistics are available.

The region may be subdivided as follows : (Fig. 2).

(1) The eastern basin or Leicestershire coalfield comprising 35 square miles of productive coal measures, of which 27 are concealed in the south. This basin lies almost entirely in Leicestershire.

(2) The Ashby anticline of unproductive coal measures, covering 11 square miles.

(3) The western basin or South Derbyshire coalfield comprising 23 square miles of productive measures, of which 9 square miles are concealed in the west and south. Only 9 square miles of this field actually lie in Derbyshire.

(4) The Coton basin, of about 9 square miles of concealed measures, which has only recently been proved and is now being developed ; it is really a western extension of the South Derbyshire coalfield.

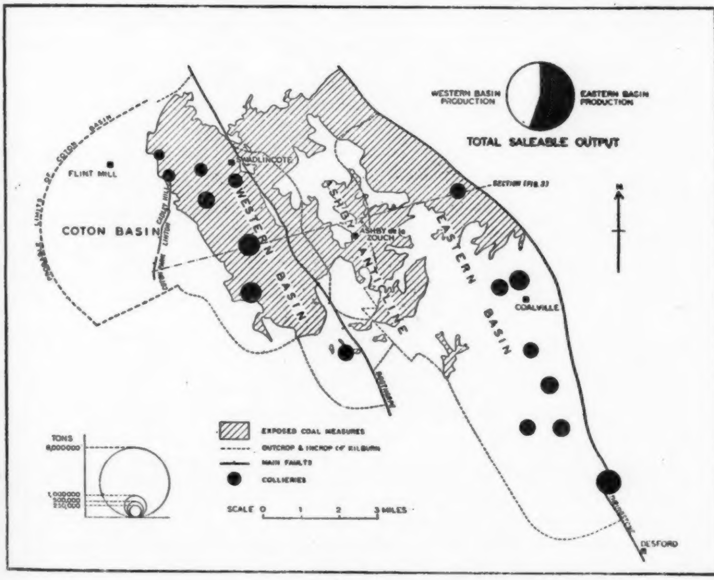

Fig. 2

The major subdivisions of the coalfield.

The figures in Table 1 illustrate the occupational structure of the region. Of the total insured labour force 40% is engaged in coal mining (which employs more than all the remaining primary and secondary industries together) and 12% in the clay industry. The figures for the engineering industries, the next largest manufacturing group, include approximately 900 employees in three large firms situated along the

southern margin of the Employment Exchange Areas which lie within the industrial periphery of Leicester. In all, 66·4% of the labour force is engaged in coal mining, quarrying, clay extraction, textile and engineering industries, and only 24% in tertiary industries, as compared with 50·6% in the United Kingdom as a whole.

TABLE 1

OCCUPATIONAL CLASSIFICATION OF INSURED EMPLOYEES, 1954
COALVILLE, ASHBY-DE-LA-ZOUCH, SWADLINCOTE

	Occupational Group.	*Male*	*Female*	*Total*	%
I	Agriculture	1,079	143	1,222	3·0
I	Mining and Quarrying	16,589	351	16,940	41·2
II	Non-Metalliferous Mining Products	4,023	1,074	5,097	12·4
II	Metal Manufacturing, Engineering	2,591	704	3,295	8·0
II	Textiles	412	1,538	1,950	4·8
II	Clothing, Footwear	77	596	673	1·6
II	Food, Drink, etc.	555	630	1,185	2·9
II	Miscellaneous Industries ..	404	439	843	2·1
III	Transport and Communication ..	1,172	154	1,326	3·2
III	Building, Contracting	2,180	63	2,243	5·5
III	Distributive Trades	1,073	1,053	2,126	5·2
III	Other Services	1,905	2,237	4,142	10·1
	Totals	32,060	8,982	41,042	100·0

I .. Primary Industries.
II .. Secondary Industries.
III .. Tertiary Industries.

Source : Ministry of Labour and National Service.

These figures conceal a significant contrast between the industrial activity in the eastern and western basins, revealed by comparing the numbers employed in only those industries lying within the physical limits of the coalfield. Coal mining remains the dominant activity in each case, employing 66% of the labour force in the Leicestershire coalfield and 60% in the South Derbyshire field. The clay industry, however, is heavily concentrated in the western basin, where it occupies 83% of all labour in this industry : industries in the eastern basin employ 83·5% of the engineering labour, 90·2% of the textile labour, and all the clothing and footwear employees. It is evident that the Leicestershire coalfield has a greater industrial diversification than the South Derbyshire coalfield ; in the former, only 71·1% of the employees are engaged in coal and clay, whereas in the latter these industries occupy 93% of the total labour force.

The area between the two coal basins, the Ashby anticline, is essentially agricultural in character and contains a few industries which account for less than 2% of the labour force in primary and secondary industries. These industries, mainly food, soap and textile firms, are in no way connected with the adjacent coal-fields except in so far as they may rely on these areas for providing labour.

Coal Production

Before examining the present production and disposal of coal from No. 7 Area, it will be helpful to review briefly the paleogeography of the area, and the past history of its coal mining industry.

The coalfield lay on the southern margin of the former Carboniferous delta-swamp which covered northern England and terminated southwards against the Midland Barrier, of which Charnwood Forest is a present day remnant. Consequently the Carboniferous deposits are much thinner in this region : wheareas in Yorkshire and Lancashire the Coal Measures are about 5000—6000 feet thick, they are only 2,000 feet, thick in South Derbyshire and 1,200 feet thick in Leicestershire. Also as a result of the marginal position of the coalfield the coal seams are generally thicker than in the north : they have coalesced and become compacted into a thinner sequence of measures.

The earth movements which occurred towards the end of the Carboniferous period, and the long period of erosion which followed, and preceded the deposition of the New Red Sandstones, had several important results, of which the more significant were :

(1) The Charnwood and Nuneaton anticlines were raised, and from them the entire sequence of Coal Measures was removed, thus isolating the Leicestershire and South Derbyshire coalfield from the Staffordshire and Warwickshire coalfields to the west and south, and from those of Nottinghamshire and Derbyshire in the north.([1]).

(2) The Coal Measures were arched to form the Ashby anticline and the entire coalfield became a downfaulted basin bounded on the east by the Thringstone fault (Figs. 2 and 3). Productive Coal Measures were removed from the Ashby anticline and remained only on the eastern and western flanking basins. The western basin was further lowered by movement on the Boothorpe fault and consequently the higher strata of the coal measure series are preserved there.

(3) The Cadley Hill fault and Linton fault (with a downthrow of 2,200 feet) have preserved an almost complete sequence of the Coal Measures beneath a cover of later New Red rocks in the small Coton basin to the west of the South Derbyshire field.

The New Red Sandstone rocks which later covered the denuded remnants of the Coal Measures were partly removed in post-Triassic times to reveal the present exposed coalfield (Fig. 2).

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(1) It is suggested that the concealed Coal Measures in the Coton basin are continuous with those of the Cannock coalfield : L. J. Wills, *Concealed Coalfields*, 1956, p. 33.

The complete Coal Measure(1) sequence consists of the Lower Unproductive Measures, the Middle Productive Measures and the Upper Unproductive Measures. The Lower Measures outcrop on the Ashby anticline and underlie the Productive Measures in the flanking basins. They have been worked only at their outcrop and only in the early stages of the exploitation of the coalfield. The Middle Productive Measures comprise the Main Coal Belt and the Clay Measures. The former has as its lower and upper limits respectively the Kilburn Seam(2) (Fig. 2) and the Dicky Gobler coal. In the Leicestershire basin the upper strata of this Coal Belt are missing, but the remainder are approximately 700 feet thick and contain 15 workable seams over 2 feet in thickness with a maximum total thickness of 82 feet. The shallowest workings are at a depth of 300 feet, and the deepest at about 1,000 feet. In South Derbyshire the complete sequence is present in the centre of the basin with a thickness of about 1,400 feet, and includes 16 seams more than 2 feet thick with a maximum total thickness of 87 feet. The shallowest workings occur at 90 feet below the surface and the deepest at about 1,400 feet. The Clay Measures, which lie above the Dicky Gobler coal and are about 300 feet thick, contain the valuable pipe and refractory clays on which the clay industry is based. These rocks are completely absent from the Leicestershire coalfield but form an extensive cover over the exposed portion of the South Derbyshire field. The Upper Unproductive Measures form a small isolated cap north of Moira, and have been proved in the Coton Basin.

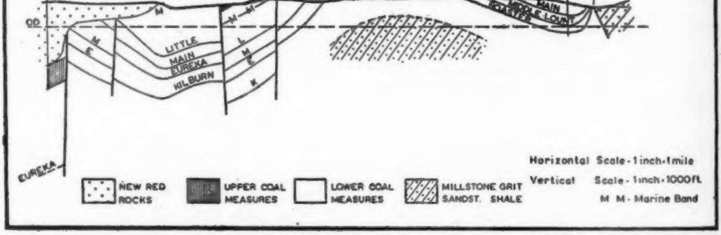

Fig. 3
Section across coalfield, west to east. (See Fig. 2.)

In the north of the Coton Basin(3) the full sequence of coal measures has been proved to lie at a comparatively shallow depth. At Flint Mill the base of the New Red Sandstone occurs at a depth of 254 feet and the Eureka seam at 1,516 feet ; in this area 12 workable seams have been proved at less than 2,000 feet below the surface.

(1) For complete detail of coalfield geology see C. Fox Strangeways, "The Geology of the Leicestershire and South Derbyshire Coalfield", *Memoirs of the Geological Survey*, 1907. G. H. Mitchell and C. J. Stubblefield, "The Geology of the Leicestershire and South Derbyshire Coalfield", *Geological Survey Wartime Pamphlet* No. 22, 1948. A. E. Trueman, *The Coalfields of Great Britain*, 1954, pp. 255-265.

(2) Heath End coal in Leicestershire.

(3) D. C. Grieg and G. H. Mitchell, "The Western Extension of the Leicestershire and South Derbyshire Coalfield", *Bulletin No. 7 Geological Survey*, 1955, pp. 38-67.

TABLE 2.

ANNUAL COAL PRODUCTION (IN TONS) IN THE MIDLAND FIELDS.

16th — 17th CENTURIES.[1]

	Middle of the 16th Century	End of the 17th Century
Trent Valley Collieries in Nottinghamshire	10—15,000	100,000
Leicestershire	1—2,000	10,000
Shropshire	6,000	150,000
Staffordshire	10,000	100—150,000
Warwickshire	2—3,000	70,000

The earliest recorded workings on the exposed coal measures date from the thirteenth century, in the neighbourhood of Swadlincote and Swannington, but coal mining did not become important until the late sixteenth and seventeenth century, when there was a general countrywide expansion of coal production (Table 2). It should be noted, however, that by the eighteenth century the output of the Leicestershire and South Derbyshire coalfield had expanded relatively much less than that of the surrounding midland fields. The coalfield maintained a comparatively small output until the middle of the nineteenth century after which the production rate increased to a peak of over three million tons per annum before the first world war and to about four million tons in 1939. The slow rate of expansion of coal mining during this period may be ascribed largely to the lack of a ready market either locally or in other parts of England. Apart from the clay industry which was developed in the nineteenth century, the coalfield itself had no large industries. This was due chiefly to the absence of iron ore in the Coal Measures and to the non-coking properties of the coal. The sale of coal in more distant markets was handicapped by the position of the field. Neighbouring coalfields to the north, west and south (Fig. 1) were better placed to supply the industrial and domestic demand in those directions while to the east the wooded upland of Charnwood hindered access to the nearest large market, Leicester. Indeed until railways were built, coal from north Derbyshire carried via the Erewash and Soar valleys could be sold in Leicester more cheaply than coal from the Leicestershire field.

The railway development of the 19th century enabled the coal to reach the ever increasing domestic markets in the east and south-east of England, and increases in production show close correlations with important stages in the progress of the railways towards London. Even so, there was keen competition in these markets from other coalfields and the pits were considered to be working full time if they averaged 4 or 5 days a week.

Until recently, therefore coal production was relatively small and adequate markets were difficult to find, but since 1939 the situation has completely altered. Between then and 1954 the output almost doubled, from 4,030,000 tons in 1939 to 7,940,000 tons in 1954, and has since been maintained at about that level. This spectacular rise in production has been due to two sets of factors. Of first importance was an increased

(1) J.U. Nef, "The Rise of the British Coal Industry", Vol. 1, London 1932, pp. 60, 65, 67, 68, 69.

national demand for coal during and after the second world war to which the coalfield was able to respond by drawing upon its considerable reserve capacity—a consequence of low production in earlier years—and by extending the working week. Secondly a combination of physical and human factors has enabled the coalfield to produce more efficiently than almost any other comparable N.C.B. Area in the country.

Since 1935 the output per manshift (O.M.S.) has risen steadily and has at all times remained above the United Kingdom average. In 1957 the O.M.S. at the face was 111·7 cwts. as compared with 67·2 cwts. for the United Kingdom ; this was the highest figure for any N.C.B. Area in the country. The overall O.M.S. has also remained high but in 1957 it was slightly bettered by No. 4 Area of the East Midlands Division. Costs, although continuing to increase, have been consistently less than the United Kingdom average, and for several years the Leicestershire and South Derbyshire coalfield (No. 7 Area) has had the lowest cost per ton of saleable output in the country. In 1957 it was 54/9·9d. as compared with the United Kingdom average of 81/5·8d. The profit per ton in 1957 was 8/4·2d. as compared with a national average of 7d. and this was only exceeded by 5 other Areas.

The most important physical factors which have contributed to these outstanding characteristics relate to the thickness, vertical distribution and depth of the coal seams. A large proportion of the production is obtained from thick seams ; a weighted average for the whole area is 4 feet 8 inches. Although the thickest seams, such as the Main Coal (10—16 feet) have been largely worked out, many of the remaining faces are between 5 and 8 feet thick. The large number of workable coal seams in a comparatively thin section of coal measures means that several seams can be conveniently worked from one shaft, e.g. in one colliery with an annual output of over 1,000,000 tons 5 seams totalling 29 feet are worked. The coal seams throughout the field lie at a shallow depth.

These advantages reduce cost, favour coalface mechanisation, permit drift mining, and improve working conditions, since underground temperatures are not high and ventilation is good.

Mechanisation began before 1900 when electric coal cutters were used by the Moira company ; by 1930 coal cutters and conveyors were commonplace, and the coalfield was one of the first in the country to be fully mechanised. Today, American "continuous miners" working in the 8 foot Stockings seam extract over 30 tons per man shift ; double shift production and longer working faces with 100% extraction have so increased output that the winding capacity of some collieries has had to be enlarged. The first drift mine was opened at Merry Lees shortly after the second world war ; since then 2 more have come into operation and 3 others are being driven or are planned. The shallow coal seams are particularly favourable to drifts which result in higher productivity with lower costs.

The importance of management and labour in coal production requires no emphasis, and it is evident from a variety of sources that this coalfield is well favoured in both respects for reasons not entirely unconnected with its geography. Its structural isolation and small compact size have enabled management and men to work closely together and develop a team spirit, which did much to smooth out the problems that accompanied nationalization and increased colliery mechanisation. The same features have helped to build a mining tradition

which has not been disrupted by an influx of workers from other coalfields. The isolation of this field and its labour from other coalfields has meant that many labour problems can be settled without fear of repercussions elsewhere. Thus changes in working methods and the introduction of large scale mechanization were achieved without labour troubles. This was partly aided by the short working week, which meant that there were few hard and fast methods of working, e.g. traditional stints,—common features of fields like Durham and South Wales with full time working. The miners accepted changes in working conditions which were likely to extend their working week and increase their incomes. The good working conditions in relatively shallow mines were further factors that minimised labour disputes.

There are at present 8 collieries working in each basin, including the drift mines at Merry Lees, New Lount, and Measham collieries but the greater proportion of the output is obtained from the Eastern Basin (Fig. 2). In both basins the better seams are now virtually exhausted, the Main and Eureka in South Derbyshire, and the Main and to a great extent the Roaster in Leicestershire. However, in the former basin there are still 8 seams of coal totalling 20-30 feet as yet unworked, and 9 seams totalling 20-45 feet in the latter. Although the declining output from some of the older mines in the coalfield may lead to closures, the projected development in the Coton basin will maintain the coalfield output at 8,000,000 tons (8,500,000 tons if Saturday working continues) for another fifty years. The total reserves in the Coton basin have been estimated at 100-200 million tons and are considered sufficient to warrant development to produce 7,000 tons a day,(1) i.e. approximately 2½ million tons a year.

Marketing of Coal

The disposal of coal by category of use is shown in Table 3. Clearly the most important consumers are electricity undertakings, industry (other than iron and steel) and domestic users; they accounted for 77·8% of the total sales in 1954 and almost 90% in 1957. During this period sales to power stations increased to 35·9%, and industry to 28·9%, whereas domestic sales fell to 24·6%. The increasing consumption of No. 7 Area coal by power stations is an important feature that will be examined later; the falling off in domestic sales may be partly attributed to an increasing percentage of small coal in the output. At the other end of the scale the gas industry, coke ovens, and export trade consumed an insignificant tonnage.

Table 3

COAL DISPOSALS FROM No. 7 AREA—1954

Consumer.	*Totals (Tons)*	%
Gas	2,023	—
Electricity	2,195,716	28·6
Railways	248,857	3·3
Coke-ovens	Nil	Nil
Iron and Steel	192,457	2·5
Other Industry	1,536,170	20·0
House Coal	2,242,495	29·2
Export and Bunkers	2,649	—
Miscellaneous	758,953	9·9
Total Disposals	7,680,865	100·0
Total Saleable Output	7,943,164	—

(1) N.C.B. East Midlands Division Annual Report for 1955.

The very large sales to power stations and industrial and domestic users results primarily from the nature of the coal, and to a lesser degree from the position of the field in the country. The coal is highly volatile, devoid of coking properties, and has a comparatively low calorific value (14,000-14,900 B.T.U. per pound, dry ash-free). It is a general purpose coal similar to the bulk of the production from the surrounding midland fields. Furthermore, the proportion of small coal is comparatively high, comprising 56·4% of the 1954 production, and is expected to increase at the rate of 1% per annum. This is due to the physical nature of the coal seams, and the high degree of mechanization. The proximity of the seams, and the need for increased production which does not always permit the seams to be worked in a correct mining sequence, result in disturbed roof and floor conditions and the consequent breaking of the coal. This is further aggravated by the absence of thick sandstones in the coal measures which means that the roofs of the working faces are weak and friable.

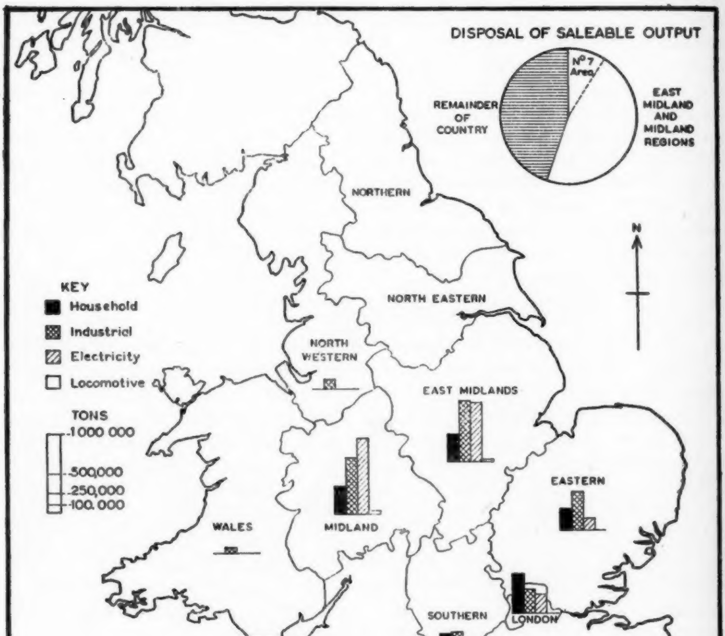

Fig. 4

Distribution of Leicestershire and south Derbyshire coal to consumer regions, 1954.

The general purpose small coal is admirably suited to the steam raising requirements of power stations and industry which claim over two-thirds of the output while most of the large coal goes to domestic users. Moreover the coalfield is well situated to serve these types of consumer in London and south eastern England, being one of the nearest midland fields to these areas.

Figure 4 illustrates the distribution of coal to Civil Defence Regions and emphasises the significance of the position of the coalfield as a controlling factor in the direction of its markets. Because of its position, the general purpose quality of the coal, and the necessity for distributing its output by road and rail (only 0·1% of the coal sold is carried by canal), the pattern of distribution to the consuming regions has been greatly affected by competition from other coalfields in the United Kingdom. Thus apart from local sales in the East Midlands, most of the coal is distributed in those regions where no coalfields exist and where transport costs, compared with those from other coalfields are competitive.(1) The large disposals to the Midland Region would appear to contradict the foregoing, but in fact fuel demands there far exceed the production of west midland coalfields.

In 1954 only 9·1% of the saleable output was consumed on the Leicestershire and South Derbyshire coalfield itself, mainly by clay industries and by collieries (including workmen's coal) ; a further 48% was sold in the East Midland and Midland Regions, and 26·1% in the London and Eastern Regions ; disposals to Wales and Northern Regions amounted to only 2·8% of saleable output. Coal for domestic and industrial purposes reaches a wide market in south and east England. Of the former, 62·8% of sales were to areas outside the two midland Regions, London being the largest market ; but half of the industrial coal was used within the two local Regions. Coal disposals to the Central Electricity Authority, however, are mainly consumed by power stations in the Midland and East Midland Regions which, in 1954, took 78·9% of the total sold for electricity generation, and in 1957 83·1% i.e. almost half the total disposals to these two Regions.

The most significant feature of the pattern of coal marketing from this field is the increasing proportion of its production going to power stations in the midlands—the result of the C.E.A. plans for the construction of large power stations on the banks of the Trent below Burton in order to export base-load power to other parts of the country(2). In 1947 29% of sales from the coalfield went to electricity generation and this percentage remained steady until 1955; in 1956 it rose to 32·6% and in 1957 to 35·9%. The actual tonnage represented by this percentage increase is more than accounted for by the disposals to three power stations, all within a few miles of the coalfield, which have come into operation since 1955. In 1956 three stations, Drakelow, Willington and Castle Donington, consumed 433,000 tons of No. 7 Area coal, and in 1957 768,292 tons, more than one tenth of total sales and about one-third of the sales to electricity production. It is estimated

(1) It must be noted that low production costs in No. 7 Area are counterbalanced by low quality and inland position, which combine to reduce the market price. In 1954, the Area had the lowest proceeds per ton in the country.

(2) See E. M. Rawstron, "Power production and the River Trent", *East Mid. Geog.*, 1954, No. 2, pp. 23-29; also "Changes in the geography of electricity production in Great Britain", *Geography*, 1955, Vol. 40, pp. 92-97.

that by 1965 the coalfield will be selling 5,000,000 tons of its coal, or 63% of its projected output, to the C.E.A., almost all of it going to neighbouring Trent valley power stations(1).

Conclusion

Throughout its long history, the coalfield has had difficulty in finding adequate markets for its low ranking coal in the face of competition from neighbouring fields. In the 19th century conditions improved when railway development provided new outlets ; in the mid 20th century a greatly increased national demand led to a doubling of the coalfield output and to the achievement of its unique characteristics of high productivity and low costs. Today we find that the coalfield is contributing an ever increasing proportion of its output to the Central Electricity Authority. In the next decade the disposal pattern will be drastically altered : no longer will it be necessary to carry coals to distant markets—the Leicestershire and South Derbyshire coalfield will be able to dispose of two-thirds of its production to power stations in its immediate vicinity.

* * * * *

ACKNOWLEDGMENT

I gratefully acknowledge the assistance of Mr. C. R. Burton, Area Marketing Manager, No. 7 Area, who has readily made available the statistics relating to production and disposal which are freely quoted in this article.

(1) When fully operational, Drakelow, Willington, and Castle Donington will consume $5\frac{1}{2}$ million tons a year.

THE CANALS OF LEICESTERSHIRE: THEIR DEVELOPMENT AND TRADE

T. J. Chandler

The historical development before 1814 of Leicestershire canals has been described by Mr. Temple Patterson(1); the present article is a complementary study for it relates local canals to their geographical environment.

Canal Construction—Physical and Economic Controls

"Had it a navigable river", wrote Burton of Leicester in 1622, "whereby it might have trading and commerce, it might compare with many of no mean rank"(2). In spite of this optimistic view, the demand for canal transport in the County was limited before the expansion of industry and population in the villages and towns of western Leicestershire in the late eighteenth century. Once constructed, however, the most important of the schemes had economic consequences which were no less real than elsewhere in the country, although in Leicestershire, the stimulus they gave was soon superseded by that of the railways.

Coal was the "dominant factor in the canal movement"(3) and the broad lineaments of the network were determined by the intense rivalry between the Leicestershire and South Derbyshire coalfield on the one hand and the Nottinghamshire and Derbyshire coalfield on the other. The detailed routes were related to local physical conditions which partly determined the relative success of the various schemes.

Leicester and Loughborough, Leicestershire's main centres of industry and population, lie in the broad valley of the river Soar which runs from south to north across the middle of the county. To the east the rocks are of mainly Jurassic age and the land rises to heights of 700 to 750 feet. The Wreak, the Soar's largest tributary, joins the river from the east a few miles below Leicester, and in the upper part of its valley lies Melton Mowbray, the leading settlement in the northeast of the County. Southeastern Leicestershire drains not to the Soar but to the River Welland on whose banks lies Market Harborough, the largest town in southeastern Leicestershire. Eastern Leicestershire supports a primarily agricultural economy. To the west of the Soar the undulating Triassic surface is broken in the northwest by the Pre-Cambrian rocks of Charnwood Forest. By contrast with the surrounding areas, Charnwood Forest has an almost montane appearance: the highest point is 912 feet above sea level and the area forms a watershed for streams flowing north and northeast to the Trent and Soar, and west and southwest to the Stratford Avon. Coal measures to the northwest of Charnwood Forest lie in two basins separated by a northwest to southeast anticline through Ashby-de-la-Zouch (Fig. 1).

There were two major deterrents to the rapid development of coal working in the Leicestershire and South Derbyshire coalfield in the late eighteenth century—the relatively small industrial demand in comparison with the larger but fluctuating domestic market, and the difficulty of communication between the coalfield and the centres of population and industry to the east and southeast. Coal was normally carried to these

areas in panniers slung across the backs of horses and mules, many of which were loaned by local farmers for the winter months([4]). Charnwood Forest, unenclosed and with few roads across its difficult terrain, was a serious obstacle to this trade([5]).

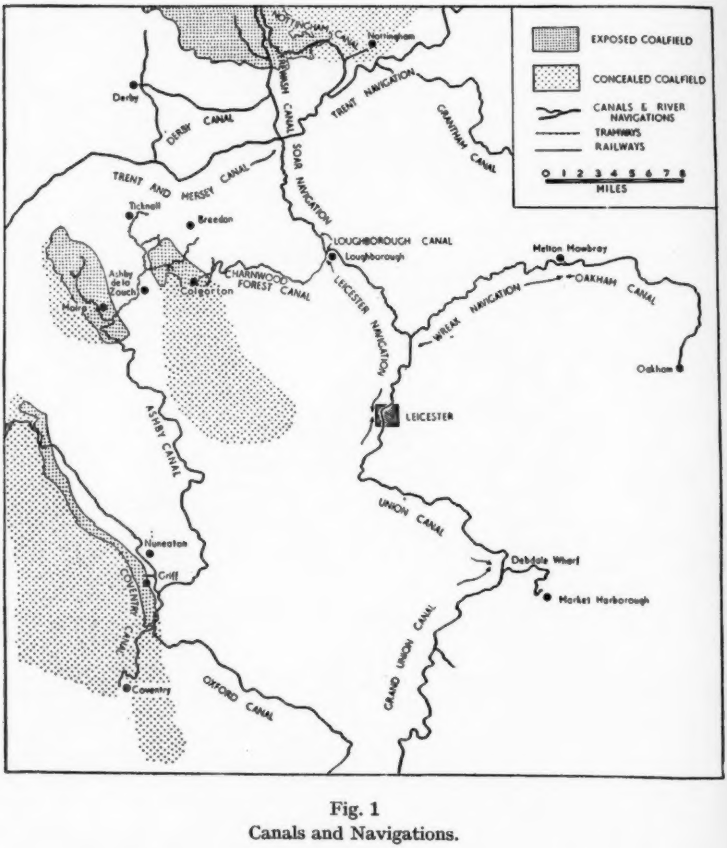

Fig. 1
Canals and Navigations.

To the north, one of the more developed parts of the Nottingham shire and Derbyshire coalfield was the Erewash valley ; the Erewash joins the Trent from the north at a point near the confluence of the Soar from the south. A larger coalfield than that in Leicestershire, it could more easily supply a strongly seasonal market and this, together with the high quality of much of its coal and the easy routeway provided by the Erewash and the Soar, stimulated the completion of the first canal in the county. This was the Soar Navigation (including the Loughborough Canal) opened in 1778 between the River Trent and Loughborough (Fig. 1). The improvement of navigation on the lower Soar necessitated only a small number of new cut-off channels and locks and its early construction also helped to reduce building costs.([6])

It was natural that there should follow a demand to extend the waterway along the Soar to Leicester but the Leicestershire coal owners were successful in insisting that the extension should not be opened to coal traffic until a canal linked their mines to the Loughborough canal basin and thereby to Leicester. The first coal barges passed along the two canals (known as the Leicester Navigation and Charnwood Forest Canal respectively) in 1794([7]) but the Leicester Navigation was by far the more easily and cheaply constructed of the two waterways ; it necessitated only a small number of locks and easily-cut canals across the necks of the larger meanders. By contrast, the Charnwood Forest Canal, owned by the same company, was a more difficult and costly venture. A rather sinuous course across the northern edges of Charnwood Forest between Thringstone Bridge and Nanpanton was made at one level, but to reach Loughborough Wharf would have necessitated many locks to negotiate the fall of 150 feet in little more than two miles. It was decided to link the eastern end of the canal at Nanpanton to Loughborough by a railway but this raised great difficulties of transhipment which were largely responsible for the failure of the whole scheme.

The Act of Parliament([8]) which sanctioned the Leicester Navigation and Charnwood Forest Canal also made provision for a waterway along the Wreak to Melton Mowbray. Two years later, the Oakham Canal Bill was passed([9]) for the extension of the waterway to Oakham. There were both economic and physical hindrances to the building of the Wreak Navigation (or Melton Canal as it came to be known). The waterway would serve a predominantly agricultural area with only a small population. The economic drive to completion was therefore small in comparison with the Leicester Navigation and the Company soon found itself in financial difficulties([10]). Also, the middle and upper Wreak has only a small catchment basin with a rapid run-off from the predominantly clay soils ; this made the river extremely difficult to navigate during summer when the rainfall was least and in winter when icing was common([11]). However, by dredging, lock-building, and the construction of by-pass canals, the navigation was opened as far as Frisby Mill by 1794([12]) and it was hoped to reach Melton Mowbray before the end of the year([13]). Work was brought to a halt soon after this and the navigation did not reach Melton until 1800 ; the Oakham Canal was finally completed in 1802([14]).

The Ashby Canal received its Act in May 1794([15]) ; the proposed waterway would connect the western basin of the Leicestershire and South Derbyshire coalfield with the Coventry Canal and thereby, the west Midlands and southern England including London. The canal followed no natural waterway and took ten years to complete although it was only just over twenty-six miles long and without a single lock. Difficulties were experienced with subsidence in the coalfield area([16]) and with the building of canal tunnels,([17]) but more serious were the early restrictions on coal production owing to disturbance of the beds by faulting,([18]) and the competition of the Warwickshire and South Staffordshire coalfields with their long-established canal links to central and southern England. The fears of those who opposed the canal Bill were thus realised([19]). Plans for a number of branch canals to connect the mines and Carboniferous Limestone quarries in the north were abandoned in favour of tramways owing to the expense and time involved in canal construction([20])—financial support was difficult to obtain during the French Wars([21]).

A further project for the extension of the canal network of Leicestershire was begun in 1794. The original plan was to link Leicester and Northampton *via* Market Harborough(22) but in 1808 it was decided to connect the partially completed canal to the Grand Junction (later called the Grand Union) Canal to London(23). Southeastwards from Leicester the canal followed the Sense, a right-bank tributary of the Soar, but soon after leaving this valley it ran into serious constructional and financial difficulties and work was halted at Debdale Wharf in August 1797(24). To the south lay the Middle Lias Marlstone scarp of the Laughton and Mowsley Hills. In 1808 a new Company, the Grand Union Canal Company, was formed to bridge the gap between Debdale and the Grand Junction Canal at Long Buckby(25). The Marlstone escarpment was crossed by a flight of ten locks with a 75 feet change of level; a branch canal to Market Harborough was opened in 1809(26), and the canal was completed in 1814(27). This Link made the Soar Navigation and Leicester Navigation part of one of the country's major north-south waterways.

The Grantham Canal, opened as far as Muston in 1793,(28) ran for part of its length through the northeastern part of Leicestershire. The canal experienced no great difficulties of construction for it followed very closely the foot of the Middle Lias Marlstone escarpment. The canal was of little economic consequence in Leicestershire for its main purpose was to supply coal to Grantham.

Early Canal Trade

Local newspapers of the time contain many accounts of the nature and extent of traffic along the Soar Navigation (and Loughborough Canal) following the opening of the waterway in 1778. Trade was dominated by the passage of Erewash valley coal southwards to Loughborough, although other goods were carried in considerable variety(29), some having moved coastwise from London.(30) Much of the coal was later forwarded by road to Leicester, the eastern part of the county, and to Rutland and Northamptonshire. By 1785, Derbyshire mines were supplying approximately 20,000 tons of the 70,000 tons of coal used in Leicestershire, Rutland and Northamptonshire per annum(31) and this was expected to rise quickly to 30,000 tons.(32)

For the Leicester Navigation, statistics enabling a fairly complete picture of early trade are available in the *Leicester, Loughborough and Mountsorrel Tonnage Accounts of the Leicester Navigation Company* for the periods between 1796 and 1809.(33) These also give details of goods passing to and from the Wreak Navigation and Oakham Canal.

At first sight it is rather strange that in 1797, several years before the completion of the waterways, considerable traffic should pass along the Wreak Navigation and enter the Oakham Canal. It would seem that the Wreak Navigation was negotiable as far as Melton Mowbray under favourable conditions of the river and a small section of the Oakham Canal had been opened in the four years since the passing of the Act in 1793.(34) River improvement on the Wreak had progressed as far as Frisby Mill by 1794(35) and records show that goods reaching Melton Mowbray were transported almost exclusively in the months that followed the spring thaw and during the autumn—the two periods of the year when the river would be most likely to be deep and navigable.(36)

Unfortunately, the tonnage records are not complete and only those for 1797 enable a summary to be made for almost a whole year (account papers are missing for only two weeks from 20 March to 1 April in 1797). Details given in these records include the origin and destination of each barge (although, apart from the tonnage to Oakham, the exact destination of goods entering the Wreak Navigation is not mentioned) and the nature and weight of its cargo. These records have been analysed and Figures 2 and 3 are based upon them.

In 1797, traffic on the Leicester Navigation was dominated by a southwards movement to Leicester and the Wreak Navigation. Over 82% of the 78,617 tons of goods carried by the waterway came from Loughborough; 58% was destined for the large domestic and industrial markets in Leicester and 20% entered the Wreak Navigation. Other wharves on the waterway between Loughborough and Leicester, such as Barrow-upon-Soar, Sileby, Mountsorrel, Cossington, Syston and Thurmaston dealt with only small proportions of the total traffic (Fig. 2) but the nature of their trade is of considerable geographical interest.

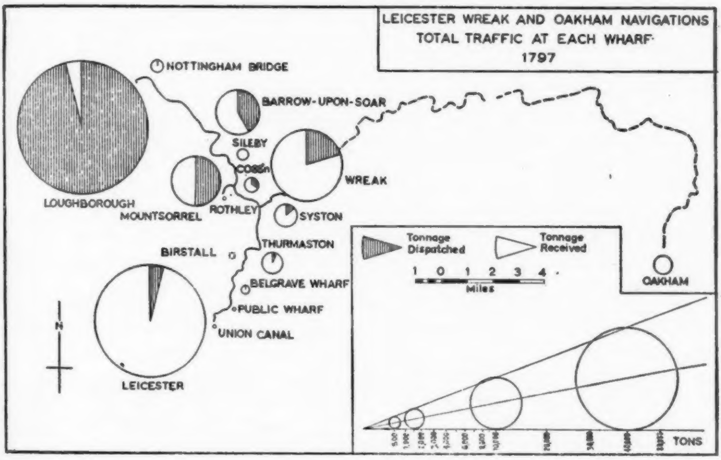

Fig. 2

Coal and coal products dominated canal traffic and were derived principally from Nottinghamshire and Derbyshire mines, although small amounts may have been carried to Loughborough from collieries near to Coleorton, 8 miles west of Loughborough.(37) Loughborough wharf dispatched 60,487 tons of coal and coal products during 1797; this represented 94% by weight of all goods sent from the canal basin. Leicester, with a population of just over 17,000 was, of course, the main market but at every wharf except Loughborough, coal was the primary import; it represented the following percentages of total receipts: Leicester 84, Barrow-upon-Soar 77, and Mountsorrel 89. More surprising is the way coal dominated the traffic leaving as well as reaching these wharves. Thus, in 1797, 12,934 tons of coal were carried up the Wreak Navigation and 3,847 tons (representing 94% by weight of all goods dispatched) moved from the Wreak to Leicester and other wharves.

Similarly, 4,023 tons of coal were carried by barges to Mountsorrel and 3,256 tons (70% of the total trade from the wharf) were dispatched, principally to Leicester.

It is extremely unlikely that the wharves obtained much coal other than by way of Loughborough wharf. The cost of overland transport would be prohibitive to any transference of Nottinghamshire coal from the Grantham Canal to Barrow-upon-Soar or the Wreak Navigation, or from the Leicestershire coalfield across Charnwood Forest to Mountsorrel. The only explanation would seem to be that traders along the Wreak and Leicester Navigations obtained coal via Loughborough and later sold it (mainly in Leicester) at a more favourable price. The return passage of coal along the Wreak Navigation is also evident from 1841 statistics(38) and was probably a constant feature of trade on that waterway.

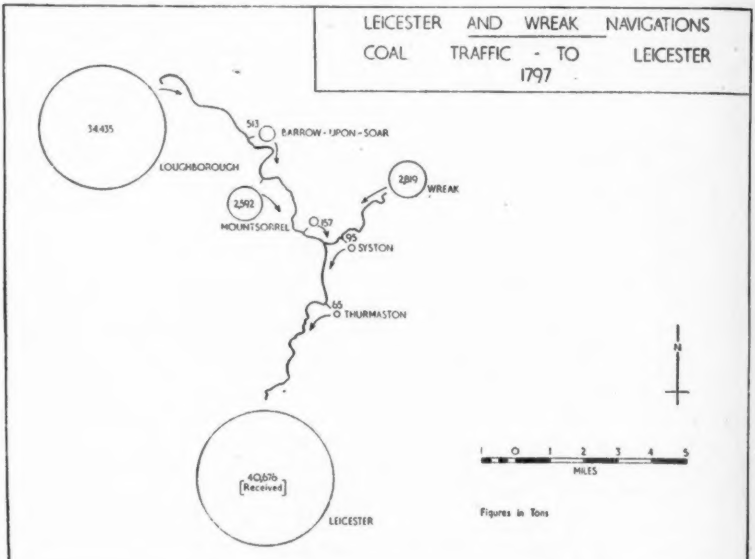

Fig. 3

Representing only a small proportion of total traffic, but of considerable local significance, was the trade in goods other than coal. The most notable of these articles were agricultural products from eastern Leicestershire, and Northamptonshire ; granite from Mountsorrel, and limestone from Barrow-upon-Soar.

During the year, large quantities of wool were dispatched from Leicester wharf to Loughborough and smaller amounts reached the town via the Wreak Navigation. There was also a limited trade in wheat, oats and barley along the Wreak Navigation and again, mainly to Loughborough. The restricted trade in agricultural goods along the Wreak was probably owing to a number of factors. First, the waterway was incomplete in the upper reaches of the river which was normally

closed for long periods in summer and winter. Second, only those agricultural areas (known as the Wolds) north of the Wreak would, by their situation, benefit by the available canal transport to Leicester and similarly, only districts east and southeast of Leicester would gain in the carriage of goods to Loughborough. The Wolds were famous for their production of barley, oats and roots(39)—all difficult to transport in primarily coal-carrying barges and more cheaply conveyed by land carriage to the nearer markets of Loughborough and Melton Mowbray. Also, similar products could be obtained from rural districts nearer Leicester, the main market in the county. But the dominant sheep-rearing districts lay in the east and southeast of Leicestershire and in Northamptonshire(40) and their wool was keenly sought by the hand spinners of Leicester, Loughborough and other towns of the Soar valley and western Leicestershire where hosiery manufacture was so important an industry. Thus in 1797, over 1,200 tons of wool were carried northward along the Leicester Navigation and more than 200 tons were conveyed along the Wreak Navigation ; in both cases Loughborough was the main market. Reduction in the price of coal following the opening of the canals(41) had, in fact, stimulated the worsted-spinning industry in Leicester and Loughborough(42) and had thereby increased the demand for local wool.

Tonnage accounts for Mountsorrel wharf show that in 1797, 880 tons of granite and 133 tons of slate left the wharf ; these together accounted for 22% of its trade. The village is sited on a narrow terrace of the river Soar at the foot of Charnwood Forest and local buildings testify to the quarrying of the nearby granite as early as the thirteenth century although the workings were probably small : they are not marked on Prior's map of 1775-7.(43) Ten years later Mountsorrel quarry is mentioned as a source of granite(44) and shortly afterwards the stone was used to surface the turnpike from Market Harborough to Loughborough(45) But the weight and bulk of granite restricted quarrying before the provision of cheap canal transport. By 1809, both Oakham and Market Harborough could be reached from Mountsorrel wharf and the popularity which Macadam gave to the system of metalling, increased the demand for road stone ; thus in this year, canal traffic in granite had increased to about 5,000 tons.(46) This probably represented almost the total production of the quarry at this time. Slate came mainly from the Swithland quarries on Charnwood Forest, 3 miles southeast of Mountsorrel.

From Barrow-upon-Soar, 782 tons of lime and 1,421 tons of limestone were sent from the local wharf in 1797 and these represented 25% and 46% respectively of its total canal trade. The local outcrop of Lower Lias argillaceous limestone had been worked since at least 1720(47), and the lime was widely used as a manure on the heavy clay-lands of eastern Leicestershire(48). Thus considerable amounts were delivered to Leicester and to wharves along the Wreak Navigation for further distribution. The canal was a notable stimulus to local quarrying but constituted a threat to the Carboniferous Limestone workings of the coalfield area(49). In addition to the coal, wool, granite and lime and limestone trade along the Wreak and Leicester Navigations in 1797, a great variety of smaller cargoes are recorded. More than 675 tons of timber were dispatched from Loughborough during the year ; this was probably Scandinavian deal brought from Hull in 'Trent Boats'.(50) The transport of dung from Leicester stables to the agricultural areas near the Wreak Navigation is also worthy of note.

Only occasional barges moved along the Charnwood Forest Canal in the years following its opening in 1794 and the tonnage accounts of the Leicester Navigation Company record the delivery (in 1796) of only sixty tons of coal to the eastern end of the canal : estimates of the possible coal trade(51) were, in fact, never realised. The whole scheme was an engineering and economic failure, and it is not surprising that after the bursting of the Blackbrook (canal) reservoir in 1799, the canal was abandoned.

For 1809, tonnage records cover only part of the year (from April to November) but they illustrate a general expansion of trade since 1797 and a maintenance of its primary characteristics : coal remained the dominant cargo although the variety of goods had increased. Pig iron and cast iron from Derbyshire furnaces were delivered to the Britannia Iron Works, first mentioned in 1804(52) and located alongside the canal in Leicester. Also, in 1809, there are records of a considerable trade in timber between Leicester and Loughborough. The extension of the waterway to Market Harborough in this year had probably initiated traffic in pit-props from the forests of northern Northamptonshire to the mines of Nottinghamshire and Derbyshire. Linen and flax were taken from Leicester to Loughborough and these too were no doubt brought from Northamptonshire via the new Union Canal.

There are no statistics of early trade along the Ashby Canal but reports in local newspapers(53) show that although traffic in coal and lime to nearby Market Bosworth, Sutton Cheney and Hinckley followed soon after the opening of the canal in 1804, the more extensive trade with the west and south of England did not develop as was expected.

Economic Consequences of Early Canal Trade

The early years of canal trade in Leicestershire had a pronounced effect upon the economy and thereby upon the population of the areas they served.

The Soar Navigation was the most successful of all the county's waterways for it was cheaply constructed and flourished on the abundant trade between a coalfield and a large market. In Loughborough a barge-building industry was begun, "large and extensive wharves" were completed and "new houses, warehouses, etc." followed its opening. Coal replaced charcoal for the comb-pots used by the woolcombers, and hand-spinning of worsted yarn, dyeing and other industries settled or expanded in Loughborough following the opening of the waterway. There was a "great resort of people" and "a face of commerce hitherto unknown at that place".(54).

Especially significant was the growth of lace manufacture in the early nineteenth century and the making of lace machinery. From 1801 to 1831, no other town in Leicestershire had such a marked growth of population—primarily the result of workers and their families seeking employment in the new and expanding trades. With the completion of the Leicester Navigation and later the Grand Union and Grand Junction Canals, the earning capacity of the Soar Navigation was still further increased and share values rose to fantastic heights : originally £142⅞ each, they stood at £4,950 in September 1824(55). The Soar Navigation brought a period of prosperity to Loughborough, but the premium it gave to the Nottinghamshire and Derbyshire field and the consequences

of the failure of the Charnwood Forest Canal, caused several pits to close in the Coleorton district, and the Leicestershire coal owners lost between 30% and 40% of their trade in the county(56). The Charnwood Forest Canal had initially raised such hopes of cheaper transport and equal competition with the Derbyshire mines that several pits had been sunk(57) but with the final bursting of the canal reservoir, many mines were closed(58) and the coalfield stagnated until revivified by the Leicester and Swannington Railway in 1832. Falling populations were characteristic of most parishes in the Coleorton and Swannington district between 1801 and 1831.

In Leicester, wharves were built and manufacturers arose "to welcome the approach of the (Leicester) navigation"(59) and the increase in industrial and commercial activity occasioned by the mere prospect of a canal was continued after it had been opened. Framework knitting and the associated worsted manufacture and dyeing dominated Leicester's trade but hosiery was still a domestic industry and although coal was used in the preparation of worsted yarn, the first steam-driven spinning mill was not opened until 1820(60). Domestic needs were substantial however, and several new industries, including engineering, sprang up near the canal which gave added prosperity to the town for over forty years(61).

The villages of Mountsorrel and Barrow-upon-Soar derived considerable benefit, like Leicester and Loughborough, from early canal trade. The granite and limestone workings lay near the waterway which carried these bulky products to many parts of the country(62).

Although the markets for coal and limestone opened by the Ashby Canal were less extensive than had been hoped, the canal encouraged the sinking of many new mines in the South Derbyshire coalfield and the population of this mining district increased rapidly in the early nineteenth century, mainly by migration from the agricultural and hosiery districts to the south.

In the rural areas of north and northeast Leicestershire, served by the Wreak Navigation and Grantham Canal, water transport had only a small effect upon the local economy. As carriers of agricultural products the canals had little attraction for reasons already mentioned, and fuel requirements outside Melton Mowbray were very small. To this market town, serving a large area of northeastern Leicestershire, the canal brought increased commerce which is partly responsible for the rapid increase of population in each decade from 1801 to 1831, rates which were not equalled again until the twentieth century.

The Leicester and Northampton Union and the Grand Union Canals had a similar effect upon Market Harborough, a complementary market town in the southeast of the County. In the first decade of the nineteenth century when it relied solely upon road transport, its market area was limited to nearby parishes. But when canals linked it to the coalfields and industrial towns to the northeast, and to the rich agricultural lands to the southeast, it benefited from the trade which developed between the two regions and its market area expanded rapidly to include not only southeastern Leicestershire but also parts of Northamptonshire as far south as Kettering(63). Market Harborough's population increased by only 0·3% from 1801 to 1811 but by 11% in the second and 17·3% in the third intercensal periods. The Leicester

and Northampton Union Canal had, of course, a far more favourable economic and physical setting than the Wreak Navigation and Oakham Canal.

Between 1804 and the opening of the Grand Union Canal in 1814, the Ashby Canal was the only one in Leicestershire with connections to London, and Mr. Pickford's decision to bring goods to Hinckley wharf instead of Brownsover wharf (on the Grand Junction Canal north of Rugby) was of considerable local significance. Hinckley replaced Brownsover as the chief distributing and reception point for canal transport between London and the East Midlands(64). From the town a great variety of goods were "regularly conveyed to and from London, all parts of the West of England, South and North Wales, Shropshire, Lancashire and Cheshire, etc"(65).

The Decline of Canal Traffic

The success of Leicestershire canals and navigations varied enormously in their early days but all suffered eventual decline and almost or complete eclipse following the opening of the railways and beginning in 1832.

The trunk waterway through the centre of the County, consisting historically of four separate enterprises (the Soar Navigation, Leicester Navigation, Union Canal, and Grand Union Canal) was the most prosperous, and competed for a long time with the new railways. Total traffic even increased for a number of years but relative trade soon declined in spite of reduced freight charges, and this was reflected in a fall in share values.

The earliest blow to the Soar and Leicester Navigations was the opening in 1832 of the Leicester and Swannington Railway. This gradually broke a monopoly of the Leicester coal market held by these canals in conjunction with the Nottinghamshire and Derbyshire coalfield. By 1845 the railway was delivering about 80,000 tons of Leicestershire coal per annum to the Union Canal at Leicester for further distribution in southeastern Leicestershire and delivery to the Grand Junction Canal at Long Buckby(66). The second great blow was the completion in 1840 of the railway from Trent to Leicester and Rugby, and the branch to Melton Mowbray opened in 1846. In the latter year the Oakham Canal was bought and closed by the Midland Railway Company and its traffic, which in the previous year had totalled 30,000 tons,(67) was lost to the Soar and Leicester Navigations. On 1 August 1877, the Wreak Navigation was voluntarily closed(68). It had none of the advantages of situation and industrial trade that had made the other canals so prosperous and with the opening of the branch railway from Syston to Melton Mowbray and the closing of the Oakham Canal, trade was reduced from 45,000 tons in 1841 to 11,000 tons in 1868(69).

Under these influences, and the building of branch railways to the Barrow-upon-Soar and Mountsorrel quarries, the tonnages carried by the Soar and Leicester Navigations fell almost continuously after 1830, revived only between 1838 and 1848 by a drastic and uneconomic reduction in freight rates,(70) and in 1927 following a six months strike of coal miners and the inability of the railways to meet all demands when the pits opened again(71).

A reduced traffic in coal from the Derbyshire field accounted for much of the decline. In 1850 the Derbyshire pits sent 125,000 tons of coal along the central Leicestershire waterways to the Grand Junction Canal at Long Buckby[72]. By 1855 this trade had been reduced to 73,000 tons, in 1894 only 4,700 tons reached Long Buckby[73] and by 1910 amounts were negligible in spite of attempts to revivify the trade,[74] But for many years, considerable quantities of coal were carried to Leicester. Nearly half the 1937 tonnage (45,425)tons and two-thirds of the 31,139 tons carried in 1947 along the Leicester Navigation was coal from Langley Mill in the Erewash valley. But by 1951, the coal trade, which had dominated so much of the canal's history, was dead and only 400 tons of goods moved southwards to Leicester.

Tonnages along the Leicester and Northampton Union Canal totalled about 230,000 tons in 1845 but in 1858, and with the opening of the railway from Leicester to Hitchin and London, the amount was reduced to approximately 120,000 tons[75]. In 1888 only 47,800 tons of goods were carried and much of this was coal supplied to the wharves at Wigston and Market Harborough, or to the Grand Junction Canal. The totals for 1937 and 1947 were about 10,000 tons and 1,500 tons respectively and the trade in these years was almost exclusively in goods from London. In 1957 the canal carried less than 1,000 tons[76].

Like the Leicester and Northampton Union Canal and the Grand Union Canal, the Ashby Canal suffered from a rather late and costly construction, but in addition, it lacked any national significance by reason of situation. Plans to continue the canal to the Trent were abandoned[77] and it was slow to develop trade with more than local markets. Share values, originally £113, never reached par, and dropped to £10 soon after opening. The first dividend was not declared until 1828[78]. But in 1833, the Coleorton Railway robbed the canal of much of its trade from the Cloud Hill Lime Works ; in 1846 the canal was bought by the Midland Railway Company and three years later an extension of the Leicester and Swannington Railway connected the Ashby Woulds mining district with Leicester and Rugby.[79] In consequence of these developments, traffic fell from 153,430 tons in 1870 (eight years before the railway opened between Ashby Woulds and Nuneaton) to 34,666 tons in 1905[80]. In the latter year, trade on the canal was dominated by coal from the Moira and Measham collieries ; about 10 % of this went to Hinckley and the remainder to Oxford, Wolvercote and Watford[81]. Traffic was seriously reduced a few years later when railway sidings were opened to these mines[82]. Trade in limestone from workings on the rims of the two coal basins in Leicestershire and South Derbyshire never reached the proportions envisaged and was negligible after the opening of the Coleorton Railway. The carriage of facing bricks from the Measham Brickworks (where Coal Measure clays were used) to London was similarly affected when the Peterborough Brickworks were opened[83].

By 1909 the Ashby Canal was in a very bad state of repair[84] and is now unused. It never achieved real success—even before railway competition.

Of the Grantham Canal running through the northeast of Leicestershire little need be said for its traffic was never large, and was of little significance in the county. It was purchased by a local railway company in 1846 and was later leased to the Great Northern Railway.[85] Little

attention appears to have been made by the purchasing company to the provision in the Act for the maintenance of the canal in a fit state for navigation,[86] and it carried only 18,802 tons of traffic in 1905 before railway and road competition forced the canal to close in 1929[87].

The waterways of Leicestershire have a significant place in the historical geography of the county. They have had both a direct and indirect influence upon the present landscape : only the central waterway, the separate sections of which were finally amalgamated with the Grand Union Canal Company in 1932, carries any traffic (1,377 tons in 1957) ; other canals remain as either weed-choked and silt-filled channels or, in the case of the Charnwood Forest and Oakham Canals, as merely scrub-covered depressions marking their former course. Indirectly, however, they have played their part in the development of the county's industry and commerce, and thereby, in the growth of its population.

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REFERENCES

(1) A. Temple Patterson, "The making of the Leicestershire canals 1766-1814", *Transactions of the Leicestershire Archæological Society*, Vol. XXVII, 1951.

(2) W. Burton, *Description of Leicestershire*, 1777, p. 146.

(3) J. H. Clapham, *The economic history of modern Britain*, 1950 edn., p. 78.

(4) J. Nichols, *History and antiques of the County of Leicester*, Vol. III, 1804, p. 1126.
T. S. Ashton and J. Sykes, *The coal industry of the eighteenth century*, 1929, p. 122.

(5) W. Gardiner, *Music and friends*, Vol. II, 1838, p. 822.
J. Monks, *General view of the agriculture of Leicestershire*, 1794, p. 86.

(6) *Leicester Journal*, 4 January 1839.

(7) Ibid., 31 October 1794.

(8) *Commons Journal*, Vol. XLVI, 1791, p. 579.

(9) Ibid., Vol. XLVIII, 1793, p. 677.

(10) Copy of the Act to enable the Melton Navigation Company to complete their navigation and discharge their debts, 1800 : Leicester City Reference Library.

(11) Second report of the select committee on railways and canals amalgamation, 1845, evidence of G. H. Betts, p. 47, and of M. W. Latham, p. 77.

(12) *Leicester Journal*, 31 October 1794.

(13) Ibid.

(14) Ibid., 7 November 1800.
Leicester Herald, 11 June 1802.

(15) Ibid., 17 May 1794.

(16) Ashby Canal Company Minute Book, 1799-1801, Report of the meeting on 27 October 1801.

(17) Ibid.

(18) Ibid., 1803, Report of the meeting on 3 October 1803.

(19) *Leicester and Nottingham Journal*, 14 September 1782.

(20) Copies of the Ashby Canal Bill, 1793, and the Ashby Canal Act, 1794 : Leicester City Reference Library.

(21) The minute books of the Ashby Canal Company, in the possession of the Transport Commission's archivist, have many references to the difficult financial position.

(22) *Leicester Herald*, 16 June 1792.

(23) *Leicester Journal*, 17 and 24 June 1808.

(24) Ibid., 11 August 1797.

(25) L.T.C. Rolt, *The inland waterways of England*, 1950, p. 55.

(26) *Leicester Journal*, 20 October 1809.

(27) Ibid., 5 August 1814.

(28) G. N. Pingriff, *Leicestershire*, 1920, p. 128.

(29) J. Throsby, *Select views in Leicestershire,* 1790, p. 277.
W. Gardiner, op. cit., Vol. II, p. 821.

(30) Ibid.

(31) *Leicester and Nottingham Journal,* 17 September, 1785.

(32) Ibid., 3 December 1785.

(33) Leicester Navigation Company : Leicester, Loughborough, Mountsorrel and Thringstone Tonnage Accounts, 1796-1809 : City Archivist's Office, Leicester Museum.

(34) *Commons Journal,* Vol. XLVIII, 1793, p. 677.

(35) *Leicester Journal,* 31 October 1794.

(36) *Second report of the select committee on railways and canals amalgamation,* 1845, pp. 47 and 77.

(37) W. Gardiner, op. cit., p. 822.

(38) Statement of coals carried down the Melton Canal from 1 October 1841 to 1 January 1842 : City Archivist's Office, Leicester Museum.

(39) W. Pitt, *A general view of the agriculture of the County of Leicester,* 1809, p. 154.
H. C. K. Henderson, "The 1801 crop returns for Leicestershire", *Transactions of the Leicestershire Archæological Society,* Vol. XXVII, 1948, p. 100.

(40) Ibid.

(41) *Leicester and Nottingham Journal,* 22 April 1780.
Leicester Journal, 31 October 1794.
W. Gardiner, op. cit., Vol. II, p. 281.

(42) Ibid., Vol. I, 1838, p. 93 and Vol. II, 1838, p. 821.

(43) Prior's Map of Leicestershire, surveyed 1775-1777.

(44) *Gentlemen's Magazine,* August 1787.

(45) J. Curtis, *Topographical history of Leicestershire,* 1831, p. xxxii.

(46) Leicester Navigation Company, Mountsorrel Tonnage Accounts for 1797 and 1809 : City Archivist's Office, Leicester Museum.

(47) T. Cox, *Magna Britannia: a topographical, ecclesiastical and natural history of Leicestershire,* Vol. II, 1720, p. 1367.

(48) W. Pitt, op. cit., p. 8.
Pigot and Company, *National Commercial Directory of Leicestershire and Rutland,* 1835, p. 109.

(49) *Leicester and Nottingham Journal,* 29 October 1795.

(50) W. Gardiner, op. cit., Vol. II, p. 821.

(51) Letter from Sir George Beaumont in the Records of the Leicester Navigation Company ; City Archivist's Office, Leicester Museum.

(52) S. Watts, *A walk through Leicester, being a guide to strangers,* 1804, p. ii.

(53) *Leicester Journal,* 3 August 1804.

(54) *Leicester and Nottingham Journal,* 22 April 1780.

(55) *The Gentleman's Magazine* September, 1824, p. 287.

(56) *Leicester and Nottingham Journal,* 17 September 1785.
Ibid., 3 December 1785.

(57) J. Nichols, op. cit., Vol. III, 1804, pp. 715 and 718.
C. Fox Strangeways, *Geology of the Leicestershire and south Derbyshire coalfield,* 1887, p. 6.

(58) J. Nichols, op. cit., Vol. III, 1804, p. 718.
C. Fox Strangeways, op. cit., pp. 7 and 8.

(59) *Leicester Herald,* 23 June 1892.

(60) *Leicester Chamber of Commerce Year Book,* 1911, p. 47.

(61) R. Weston, *Leicester Directory,* 1794, p. i.

(62) *Third report of the royal commission on canals and inland waterways,* 1909, p. 74.

(63) J. Bland, *Bygone days in Market Harborough,* 1924, p. 48.

(64) Ashby Canal Company Minute Book ; minutes of meetings held on 17 and 22 March 1802, and 19 April 1802.
Leicester Journal, 2 April 1802.
Ibid., 3 August 1804.

(65) Ibid., 29 March 1805.

(66) *Second report of the select committee on railways and canals amalgamation,* 1845, p. 47.

(67) Ibid.

(68) Copy of the Act for closing the Melton Canal, 1877 : City Archivist's Office, Leicester Museum.
(69) *Second report of the select committee on railways and canals amalgamation*, 1845, p. 77.
Return to the House of Commons from all inland navigation and canal companies, 1870, p. 8.
(70) *Report of the select committee on railways and canals amalgamation*, 1845, p. 36.
(71) G. Cadbury and S. P. Dobbs, *Canals and inland waterways*, 1929, Appendix 1.
(72) *Second report of the royal commission on canals and inland waterways*, 1907, p. 65.
(73) Ibid.
(74) *Fourth and final report of the royal commission on canals and inland waterways*, 1910, p. 37.
(75) W. White, *History, Gazetteer and Directory of Leicestershire*, 1846, p. 30.
Return to the House of Commons from all inland navigation and canal companies, 1870, p. 8.
(76) Information supplied by British Transport, Inland Waterways Executive.
(77) Ashby Canal Co. Minute Book ; minutes of a meeting on 30 June 1800.
(78) *Leicester Journal*, 23 May 1828.
(79) C. E. Stretton, "History of the Ashby and Nuneaton joint railway", *Railways of Leicestershire—a summary*, 1900, p. 117 : Leicester City Reference Library.
T. J. Chandler, "Communications and a coalfield", *Transactions and Papers of the Institute of British Geographers*, 1957, pp. 163-173.
(80) *Second report of the royal commission on canals and inland waterways*, 1907, Appendix 19, Statement 12.
(81) *Third report of the royal commission on canals and inland waterways*, 1909, p. 205.
(82) Ibid., p. 206.
(83) Ibid., p. 207.
(84) Ibid.
(85) C. E. Stretton, op. cit., p. 10.
(86) *Report of the royal commission on canals and inland waterways*, 1906, p. 236; 1907, p. 233 ; 1909, p. 72.
(87) *Fourth and final report of the royal commission on canals and inland waterways*, 1910, p. 87.

AN INVESTIGATION INTO THE EFFECTS OF THE EAST MIDLANDS EARTHQUAKE OF FEBRUARY 11th, 1957, ON VIBRATION-SENSITIVE RELAYS AT LOCAL POWER STATIONS

G. Lees

In a previous number of the *East Midland Geographer* a short account was published of some of the local effects of the East Midlands Earthquakes of February 11th and 12th, 1957.(1) Reference was made in the closing paragraph of that account to an investigation which was proceeding into the accidental operation (i.e. 'tripping') by the tremor of the 11th February, of seventeen electrical plant-protection relays at five East Midlands Power Stations. That investigation is now complete and the present account is a brief non-technical summary of the chief findings.

Two kinds of relay were affected by the earth movements, both being designed to protect valuable plant from damage in the event of the development of electrical faults. One of the relays depends for its normal operation on the electro-magnetic attraction of a pivoted clapper (the 'P. & B'. relay) and the other on the tilting of a small closed cylindrical glass tube to such an angle that the mercury contained in it makes an electrical contact between two points embedded in its upper side (the Buchholz relay). Both of these movements may be induced by vibration or shock, naturally or artificially produced, as well as by the development of electrical faults in the power plant. An American Project Committee, set up in 1950 to investigate accidental tripping of relays, did describe tripping of similar relays by traffic vibration, heavy knocks, etc., but no reference was made to accidental tripping by earthquakes.

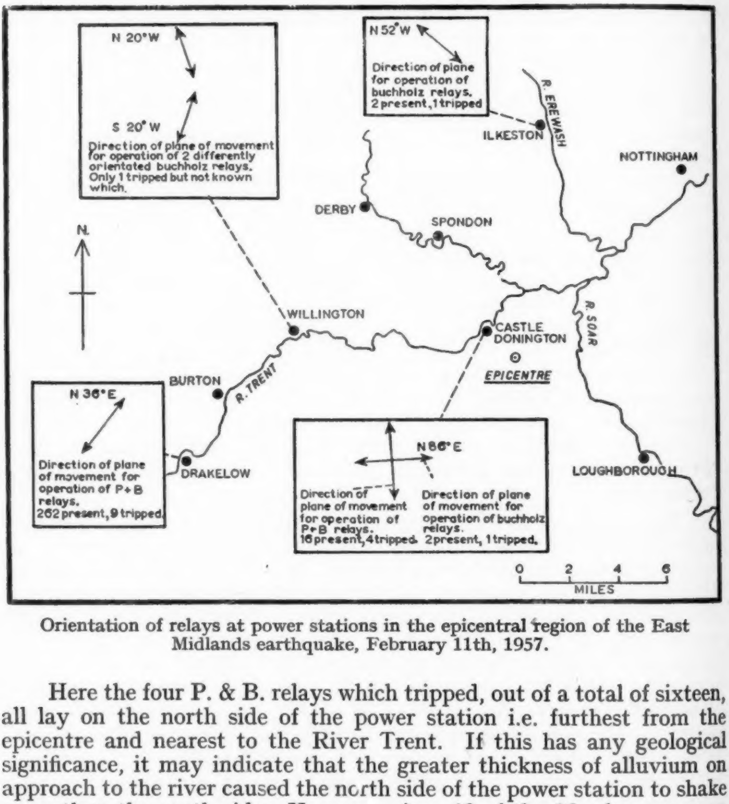
Experiments carried out in the Mechanical Engineering Department of Derby and District College of Technology, on one of the 'P. & B'. relays, made available for the purpose by the manufacturers, showed that they would be more susceptible to earth waves travelling in certain directions than to waves travelling in others. Accordingly it was thought worthwhile to plot the positions and orientations of affected and unaffected relays in the earthquake area in order to ascertain if there was any regularity or pattern in the failures, which would allow deductions to be made regarding direction of wave travel through the power stations. The idea of attempting to find out the direction of wave travel from earthquake damage is very old, Mallet in 1857 endeavoured to locate the epicentre of the great Naples earthquake by observation of overturned columns and walls. It is now generally recognised, however, that such events depend to a very great extent on the character of the ground locally, and it is well known that seismic waves are refracted on passing across the boundary between rocks of different density and elasticity. Consequently it was fully appreciated before this investigation

(1) *East Midland Geographer*, No. 7, June, 1957, pp. 52-53.

began, that any directions obtained by plotting movements of relays were likely to give more information on direction of wave travel through a certain place than to indicate the position of the epicentre.

ACCIDENTAL TRIPPING OF P. & B. AND BUCHHOLZ RELAYS AT CASTLE DONINGTON POWER STATION.

Only one of the six generators of this new power station was completed and in operation at the time of the earthquake. The Turbine House lies very close ($1\frac{1}{2}$ miles) to the north-west of the calculated epicentre of 52° 50′ N, 1° 20′ W. The station is situated on the South side of the River Trent sited on Trent alluvium (sands and gravels) but founded on a raft of concrete 22 feet thick which penetrates the 15′ to 20′ of alluvial deposits into Triassic sandstones and marls.



Orientation of relays at power stations in the epicentral region of the East Midlands earthquake, February 11th, 1957.

Here the four P. & B. relays which tripped, out of a total of sixteen, all lay on the north side of the power station i.e. furthest from the epicentre and nearest to the River Trent. If this has any geological significance, it may indicate that the greater thickness of alluvium on approach to the river caused the north side of the power station to shake more than the south side. However, since 13 of the 16 relays were on the north side and only 3 on the south, the fact that all 4 of those tripped were on the north side may have been just pure chance.

Also at Castle Donington, there occurred the tripping of one Buchholz relay. The special significance of this lies in the fact that its plane of movement, for tripping to take place, lies perpendicular (i.e.

E/W) to that of the P. & B. relays (i.e. N/S). Since the epicentre lies due S.E. of the power station, the inference is that the earth waves travelled in an approximately direct line from their source so as to have strong components in both E/W and N/S directions on arrival at the site. It is considered unlikely that the shock wave which produced the trip was near vertical, from the earthquake focus at depth, since experiments on the P. & B.relays showed that they were more than twice as vulnerable to horizontal shake as to vertical, and the same tendency towards vulnerability would be shown by the Buchholz mercury switch.

A second major point of interest regarding the typical Buchholz relay at Castle Donington is that this relay was one of two on the site, and the other, identically mounted, was unaffected although situated only 450′ away. It is to be noted that the relay which operated was the one closest to the river. There thus seems reason to think that the north-west end of the power station nearest the river was shaken more than the south-east, in which direction lay the epicentre.

Accidental tripping of P. & B. relays at Drakelow Power Station

At Drakelow Power Station, 14 miles S 73° W of the calculated epicentre, only P. & B. relays were affected by the tremor. Their plane of movement to effect tripping was S 36° W / N 36° E, which means that a direct line from the epicentre is 37° away from the direction of this plane. This is considered a large angle to produce tripping at so great a distance, and two facts have suggested that the earth waves may have come not direct from the epicentre, but may have been refracted along the course of the Trent (and possibly intensified by the unconsolidated nature of its alluvial deposits).

These facts are first that only relays at the north-west end of the power station were affected (i.e. closest to the River Trent). Seven were tripped on the machine nearest the river, two on the next and none on the remaining two machines at the south-east end of the station. On each machine there was a total of sixty-five relays. Secondly, the line of the Trent and its alluvial channel at Drakelow is the same direction as the plane of movement of the relay hammers, namely S 36° W / N 36° E.

It appears much more likely that tripping would be caused by an impulse from a direction along the line of possible movement of the relays when 100% of the force received is directed towards producing the movement, than when the impulse comes at an angle of 37° and only 80% of the total force is so directed.

Accidental tripping of Buchholz relays at Spondon, Willington and Ilkeston Power Stations (6, 9 and 10 miles respectively from the Calculated epicentre)

Uncertainty among the staff of the Power Stations at Spondon and Willington, as to detail concerning the tripped relays prevented any conclusions concerning direction of wave travel being made, but at Ilkeston one of the two relays, separated by only 30 feet, identically mounted and oriented, was tripped and again it was the one nearest the river (River Erewash)

The line of movement of the relay for tripping to occur is at a very high angle (65°) to the direct line from the epicentre, but only 30° away from the trend of the Erewash valley. If these two directions are compared as possible directions of wave approach, in the former case only 42% of the force received would be directed towards tripping, compared with 87% in the latter.

Conclusions

While the facts connecting the occurrence of tripping of relays with proximity to a river and/or direction of a river valley may appear tenuous evidence if taken separately, nevertheless the evidence gains strength when facts from all sources are considered together. In all four cases where some relays of a particular type tripped and others of the same type did not, it was those closest to the river and consequently closest to the maximum thickness of alluvial deposits in the river-bed, which operated. In addition there is the evidence from Drakelow and Ilkeston to suggest that earth waves may be refracted along river courses and so be more likely to affect relays having a line of movement parallel to the valley than relays oriented so that their tripping movement is in a plane at right angles to the valley trend.

Other macroseimic evidence, concerning the direction of fall of chimneys, and the setting in motion of freely swinging objects, in the Derby area, mentioned briefly in the earlier article of June '57, also tends so far as it goes, to support the association of direction of earth waves with direction of river valleys. Although the epicentre lay due S.E. of Derby, most of the evidence collected seemed to indicate that the waves travelled through the town from a more easterly direction, and it is to be noted that the trend of the River Derwent between Derby and the epicentral zone is approximately E.S.E.

The dislocation of public power supplies by accidental tripping of electrical relays was, in the case of this earthquake only slight, though plant was put out of action for several hours in some cases, while non-existent electrical faults were searched for and the necessary checks were made. The electrical grid system covering this country is well able to cope with minor irregularities and keep the supply to any area constant in spite of fluctuations in output in a local group of power stations. However, if more severe earthquakes were to cause more extensive tripping of relays then power supplies might well be reduced or even completely cut locally. We are fortunate in these islands in the rarity of our earthquakes, and the chances of severe dislocation of power supplies by these disturbances must be reckoned as slight. But it is worth considering that explosions, especially those of a nuclear type give rise to considerable earth tremors that might well cause many relay failures, of the kind described, in power stations over a wide area and so result in a general breakdown in electricity supplies at a critical time. Much, however, can be done to minimise the risk of accidental operation of relays by modification to the relays themselves, and action is already being taken along these lines. For example, the writer understands that the Metropolitan Vickers Electrical Co. Ltd. has now modified the design of the Buchholz relay in order to make it less susceptible to shock or vibration; while the Divisional Technical Engineer of the East Midlands Division of the Central Electricity Authority also noted, in his report to the Divisional Controller, that the P. & B. clapper type of relay could

be made less susceptible to shock if the tension on the coil spring regulating its operation were increased and that this could safely be done without reducing its efficiency. Further in this connection, the American Project Committee previously mentioned, reached the following conclusions regarding accidental operation of relays : first that plunger-type relays are less susceptible than clapper-type, and secondly that vibration may be considerably reduced if panels are constructed of slate or a composition instead of steel, and/or mounted on rubber, and/or more adequately braced.

Finally it has been noted in the course of this account that the reorientation of relays with respect to the valley in which the conventional power station invariably lies, may have some influence on their behaviour during earth tremors, but it is realised that attention to details of the construction of relays is far more likely to reduce risk of tripping than to attempt a reorientation of all the relays of these two types, even if that were possible. However, apart from spotlighting the need for improved designs in these instruments, perhaps the main interest in the investigation is the further support it gives for Gutenberg's and other authors', demonstrations that in earthquakes the intensity of the shock experienced on alluvial ground is usually considerably greater (up to three times as great according to Gutenberg) than that experienced on firmer terrain, and in the suggestion which it makes that refraction of seismic waves may take place along the course of river channels. Seismic-wave refractions have long been recognised in the vertical plane, so refractions in the horizontal plane of the earth's surface may not be unexpected.

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REFERENCES

(1) E. Tillotson, 62nd annual report of the Seismological Committee, *Advancement of Science*, Vol. XIV, No. 55, December 1957.

(2) A. T. J. Dollar, "Midlands earthquake of February 11th," *Nature*, March 9 1957.

(3) "Effect of Shock and Vibration on relays", *Transactions of the American Institute of Electrical Engineers*, III Vol. 74, 1955, pp. 398-401.

(4) B. Gutenberg, "Effect of ground on shaking in Earthquakes", *Transactions of the American Geophysical Union*, Vol. 37, No. 6, December 1956.

(5) B. Gutenberg, and C. F. Richter, "Earthquakes, Magnitude, Intensity, Energy and Acceleration" (2nd Paper), *Bulletin of the Seismological Society of America*, Vol. 46, No. 2, April 1956.

(6) H. Benioff, "The physical evaluation of Seismic Destructiveness", *Bull. Seism. Soc. Am.*, Vol. 24, No. 4, October 1934.

(7) K. Sezawa and K. Kanai, "Energy dissipation in seismic vibration of actual buildings", *Bulletin of the Earthquake Research Institute*, XIII, Part 4, 1935.

(8) J. R. Thoenen and S. L. Windes, "House movement caused by ground vibrations", *U.S. Department of the Interior Bureau of Mines*, December 1938.

EAST MIDLAND RECORD

Derby and Railway Modernisation

The modernisation plan for British Railways was published in January 1955. It announced, among other changes, the scheme for the gradual replacement of steam by electric, diesel and diesel-electric traction. Railway companies in Britain have themselves for very long built most of their own rolling stock, which has until recently been nearly all steam hauled except on a large part of the Southern Railway system. The modernisation plan was soon followed, therefore, by a statement of the policy to be adopted in railway workshops. It was announced that, while repairs and maintenance were as far as possible to be carried out on all stock both old style and new in railway workshops, diesel and diesel-electric machinery and rolling stock were in general to be purchased from private manufacturers. Thus the nineteen engineering shops controlled by British Railways were to participate only slightly in the construction of the new types of equipment and, apart from repair and maintenance, were to continue primarily as builders of steam locomotives and conventional rolling stock. The workshops, as equipped at the time, were of course better suited for this type of production.

This policy was modified when the rate of modernisation was accelerated in 1957. The acceleration involved the earlier replacement of steam locomotives by other forms of power and by 1958 the manufacture of the traditional "railway engine" had ceased in railway workshops except for the largest type of goods locomotive (class 9, 2-10-0). This type is being built at Crewe. It was decided, therefore, to undertake the construction of some diesel and diesel-electric stock in those railway workshops which were economically and technically most suitable.

The Locomotive Works and Carriage and Wagon Works at Derby, the only engineering shops in the East Midlands, were chosen as a major centre for the new types of construction. The works employ about 9,000 people and are among the largest in Britain. Originally the engineering headquarters of the Midland Railway, Derby was selected for this purpose largely because the town was a terminal point and locomotive depot for each of the three companies which amalgamated in 1844 to form the Midland Railway system.

Even before nationalisation the Derby works had begun making diesel-electric shunting engines for the L.M.S. Railway and by December 1956, 331 diesel locomotives had been built. Thus Derby had strong claims to a large share in the diesel construction programme. This is now in progress and it was planned that in 1958 Derby should produce 81 diesel-electric shunters and 13 main line diesel-electric locomotives of up to 2,300 horse-power. While five other railway works are engaged in diesel construction, only Derby and Swindon are so far building main-line locomotives for all Regions of British Railways.

Derby has a large share too in the production of multiple-unit diesel sets for local passenger train services of the kind now running in many parts of Britain and has been responsible for building many of the multiple-unit sets now operating in the East Midlands and in East Anglia. These sets are assembled at the Carriage and Wagon Works where 256 units were scheduled for construction in 1958. Swindon too

is building similar stock but the Derby output, which should account for 22% of the total ordered by the Transport Commission in 1958, should amount to 55% of sets made at workshops of British Railways. No conventional passenger carriages are at present being built in the Derby works, but 3,100 freight wagons were to be constructed in 1958.—B.J.T.

Oil Production in Nottinghamshire

The output of crude oil in Nottinghamshire, the only area of commercial production in Britain, has been considerably increased by supplies from the newer wells at Egmanton. Earlier reports of the discovery of oil in this district and in the Vale of Belvoir appeared in the June 1956 and June 1954 issues of this periodical. At present there are thirteen wells in production at Egmanton all of them within easy reach of the main railway line at Tuxford, by means of which the crude output is sent to Scotland for refining. Thus there are now three centres of production in all, the Eakring-Dukes Wood field and its subsidiary groups of wells at Kelham Hills and Caunton—the oldest area, from which supplies are now diminishing; the Vale of Belvoir around Plungar; and Egmanton. In the past few years the total output from an aggregate of 300 wells has risen from 53,000 tons in 1955 to 82,000 tons in 1957. These amounts however are less than the 120,000 tons produced from the Eakring area alone during the peak-period of 1943-44. The value of the Nottinghamshire oilfield however does not lie wholly in its small contribution to the country's requirements, for it is also of great value as a training ground for technicians, i.e. geologists, drilling teams and petroleum engineers destined to work abroad in the great oilfields of the world.—K.C.E.

A Lead Mine in Derbsyhire

The Riber Lead Mine near Matlock, Derbyshire, is possibly the only lead mine now working in this country, although other mines producing associated minerals (e.g. fluorspar) yield a little lead as a by-product. This ancient mine was re-opened in 1952, after being closed for a hundred years, its renewal being stimulated by the increased demand for lead following the outbreak of the Korean War.

The mine is situated on the east side of the River Derwent in Carboniferous Limestone. Entrance to it is by an incline 1,100 ft. long, dug at an angle of 17° to the horizontal, the limestone itself having a dip of about 10° to the east. Up this incline the ore is hauled in tubs by means of wire ropes. The limestone is interrupted by a basalt lava bed about 80 ft. thick, above which are the lead veins. A vertical shaft however has been cut through the lava to the limestone beneath, where further veins exist. The present operations are about 80 ft. below the level of the Derwent, though they do not actually extend under the river. Water is a problem and must be pumped out at the rate of 100 gallons a minute to prevent the mine from being flooded.

Two veins are being worked, the Great Rake and the Coal Pit Rake. Both were known to the miners of the past, picturesquely termed the "Old Man" by miners of today. Indeed, the "Old Man" had also penetrated below the water-table, the water being kept down by pumps, a specimen of which was recently discovered when some old workings were reached. The pump, difficult to date precisely as it was of a type in use from Elizabethan days to the beginning of the eighteenth century, has been sent to the Science Museum in London. It may have operated as part of a system, along with other pumps and tanks at different levels, to raise water to the surface.

The lead veins vary in thickness from nine feet down to a few inches, but in general it is uneconomic to work a thickness of less than eighteen inches. The richness of the ore also varies considerably in the vein. Thus lead mining can be highly speculative, because in order to pursue a particular vein it may often be necessary to tunnel where it is thin in the hope that it will eventually open out to a profitable width. The ore is extracted first by blasting two tunnels, one at the top of the vein to determine its extent, and another immediately below the vein. The mineral is then cut from the roof of the lower tunnel and allowed to accumulate as a platform on which the miner can stand until the whole "slice" between the tunnels is loosened and can be removed by conveyor to the tubs. The Riber Mine employs about eight men and yields up to 100 tons of ore a week.—P.S.M.

HIGHER DEGREE THESIS AND FIRST DEGREE DISSERTATIONS

Prepared in the Department of Geography.

In the University, Geography may be read as a subject in the Faculty of Arts, under the Board of Studies in Law and Social Science (Faculty of Arts) and in the Faculty of Pure Science. Since the award of the Charter to the University in 1948 all students taking an Honours degree in Geography have been required to submit a dissertation as part of their final examination. Only those dissertations and higher degree theses relating to East Midland subjects are listed below. *Bona fide* students or research workers may be permitted to consult them on application to the Department.

1958

M.A.

The local accessibility of Nottingham, Derby and Leicester. P. A. Brown.

Population and settlement in Kesteven (Lincs.) c. 1775—c. 1885. D. R. Mills.

Ph.D.

The geographical aspects of changing economic patterns with special reference to East Nottinghamshire and West Cumberland. K. A. Hornsby.

DISSERTATIONS.

Agriculture, rural industry and settlement in south east Leicestershire. D. J. Gillyean.

The upper Derwent and Wye valleys : a geographical comparison. A. Marples.

Recent changes in the economy of Gainsborough. D. P. Matthews.

The development, morphology and industry of the city of Leicester. J. E. Springthorpe.

A study of three Derbyshire parishes : with special reference to the agricultural geography. J. A. Turner.

The growth and industry of the Hinckley Urban District. D. C. Wakefield.

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